THE

JOURNAL OF GEOLOGY

JULY-AUGUST, 1895.

NOTE ON THE GLACIAL DEPOSITS OF SOUTHWESTERN ALBERTA.

In the *Geology and Resources of the Forty-ninth Parallel* (1875), the writer first gave some account of the superficial deposits and glacial phenomena of that part of the Great Plains now included in the district of Alberta. This was followed, in the *Report of the Geological Survey of Canada* for 1882–84, by a somewhat more complete presentation of the facts relating to the same region. Since that time considerable areas of the adjacent plains have been examined by Messrs. McConnell and Tyrrell, much further information has been obtained respecting the Cordilleran region and many very important advances have been made in the study of the glacial period in North America generally. It thus appeared to be desirable that some further examination should be made, by way of revision and addition, in this region in which the Great Plains border upon the Rocky Mountains, and with this object, the writer, accompanied by Mr. R. G. McConnell, spent some time there in June 1894.

The main points which seemed to require attention were those connected with the relation of the eastern and western drift along the slopes of the mountains, the western limit of the former and the nature of this limit. It appeared probable that facts of value might, in particular, be obtained in the Porcupine Hills, which rise to heights exceeding 5000 feet, at a distance of from

twenty to thirty miles east of the Rocky Mountains, where, if anywhere, the highest margin of the glacial deposits should be marked either by moraines or by beach-lines.

In the course of a much closer examination of these hills than had previously been possible, it was in effect found, that they show a series of terraces, running up from about 3200 feet to a maximum height of 5300 feet above sea level, and that drift from the Laurentian Plateau, on the east and the Rocky Mountains on the west occurs, as well-rolled shingle, up to the highest level of these terraces and no further. The elevation is nearly three times that of the Laurentian Plateau, and the circumstances show that the Laurentian and Rocky Mountain stones reached these high levels at the same time.

A comparison of the highest levels of the drift in several places in southwestern Alberta, indicates the existence of a tract of greatest depression and of subsequent maximum elevation in a part of that district, and probably that of a series of nearly parallel isobases of decreasing amount to the northeastward of this tract, trending east-southeast by west-northwest, but turning to a northwesterly direction (corresponding with that of the mountains) further to the northward.

Whether the upper limits of glacial deposits be accepted as the shore-lines of an extended body of water, as marking the surface level of a *mer de glace* or as the margin of a glacier-dammed lake, enormous changes of level in the region must equally be admitted.

A search for eastern erratics upon higher parts of the foothills, in certain localities somewhat extends the spread of this drift to the westward, beyond the line drawn for it by me upon previous maps. These erratics in fact become quite sporadic in their distribution on approaching the mountains.

Some years ago, while examining the sections of glacial deposits along the Bow Valley, eastward from the mountains, Mr. McConnell found reason to believe in the existence of a "western" bowlder-clay which changes gradually to the east into the typical Saskatchewan gravels of the plains. This observation has

now been confirmed, and it follows from it and from the inferior position of the Saskatchewan gravels to all the previously recognized glacial deposits of the plains, that we have in this region no less than three bowlder-clays to reckon with. The earliest of these is derived entirely from the Rocky Mountains and does not, as a bowlder-clay, extend very far from them. The two later bowlder-clays contain stones of mixed eastern and western origin, each variety preponderating in the direction of its origin. A general section of the drift deposits of the region, as now understood, thus shows, in descending order:

1. Silts, sands and gravels.
2. "Upper" bowlder-clay.
3. Inter-glacial deposits.
4. "Lower" bowlder-clay.
5. Saskatchewan gravels derived from "western" bowlder-clay.

It is not quite certain to which of these deposits the high-level terraces and shingles correspond, but it appears probable that they may be assigned to the time of the "upper" bowlder-clay or to that of its close. Neither is it yet definitely known whether the "lower" or "upper" bowlder-clay of the plains extends furthest in toward the base of the mountains. In the absence of the inter-glacial beds, no satisfactory means of distinguishing these deposits in isolated exposures has been found.

It is hoped shortly to publish in sufficient detail the observations upon which these preliminary statements depend; but without entering at all into the question of the mode of origin of the several deposits, it may be of interest here to note their possible relation to those of the glacial epochs or stages recently classified by Professor T. C. Chamberlin. The "lower" bowlder-clay of the plains of western Alberta, may I believe be pretty certainly correlated with his first or Kansan formation, in which case the inter-glacial deposits of the Belly River would represent the Post-Kansan interval and the "upper" bowlder-clay of the same region the Iowan formation. Like the Iowan

formation the "upper" bowlder-clay is characterized by abundant associated silty beds, and no extensive moraine-like deposits are known to be connected with either the "lower" or "upper" bowlder-clays. Further eastward, the northern continuation of the Missouri Côteau to the North Saskatchewan may indicate the limit of the Wisconsin formation. It is at least notable that beyond the Côteau a well-marked system of eroded valleys exists,[1] which finds its limit at the Côteau in a manner much resembling that ascribed to the valleys of the Post-Iowan interval.

According to the scheme of correlation suggested above, it will be observed that the "western" bowlder-clay must represent an epoch of glaciation antecedent to the Kansan. There can be but little doubt that this corresponds with the time of maximum development of the Cordilleran ice-sheet, but as there was at least one subsequent epoch of important development of this ice-sheet, I would suggest that this stage may be named "Albertan." The Albertan "formation" to comprise both the "western" bowlder-clay and the derived Saskatchewan gravels.

We may further, although with some reserve as yet and provisionally, accept the hypothesis that the Saskatchewan gravels are contemporaneous with the Lafayette gravels, and in this case the suggestion made by Professor C. H. Hitchcock in a late number of the *American Geologist*[2] that the Lafayette gravels represent in the East a glacial epoch earlier than any of those of Professor Chamberlin's classification (which it must be remembered is based upon the region of the Laurentide glacier only) would be substantiated. The bowlder-clays of this epoch may have been obliterated by later events in the East, but still remain unchanged along the base of the Rocky Mountains. Professor Hitchcock further suggests in the same note that the two periods of maximum moisture in the Great Basin may correspond with his supposed first epoch of glaciation and the Kansan epoch, a hypothesis which would correspond very well with that here proposed.

[1] Geology and Resources of the Forty-ninth Parallel, p. 230.

[2] Vol. XV., p. 330.

The migration of the great center of glaciation from the northern Cordillera to the Laurentian Plateau must have been intimately connected with the very notable changes in relative levels which have already been alluded to.

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June 10, 1895.

EXPERIMENTAL APPLICATION OF THE PHOTO-TOPOGRAPHICAL METHOD OF SURVEYING TO THE BAIRD GLACIER, ALASKA.

It is believed that the method of photographic surveying, as developed by Mr. E. Deville, surveyor general, Dominion of Canada, will prove of great assistance to those engaged in the study of the motion of glaciers. The method is briefly described by the writer in the annual report for 1894 of the Association of Ontario Land Surveyors.

While engaged at other work in connection with the Canada-Alaska boundary survey,—Mr. W. F. King, H. M. Commissioner,—during the past season (1894) I embraced the opportunity of taking a number of views of the Baird Glacier, Thomas Bay, from the same stations and at different times for the purpose of studying its motion near its termination. The stations occupied were three in number, all situated on the fluvio-glacial plain which extends for upwards of half a mile between the glacier and the sea. The bases used were 865 and 2065 feet in length, and were measured with a tape, and their azimuth determined with a transit from solar observation. Mountain peaks and other fixed points within the photographic field were also read upon, for the purpose of orienting the views. Two crossed rings were painted on the rock bordering the east side of the moraine and tied to the triangulation for future reference, should any one again take observations or measurements of the glacier. The work done is but a small part of what might or should be done for a complete study of the motion of the glacier in all its parts. This was beyond my sphere and the time available. However, the little that was accomplished will show satisfactorily the applicability of the camera for the study of glacial motion, and also give some facts regarding the motion of the Baird Glacier.

It may be interesting to state how I proceeded to arrive at the results hereafter given, and to point out the difficulties encountered.

From views taken from the 865-foot base,—about 1700 feet from the glacier, which has a frontage of a mile—I plotted that part of the glacier that was intervisible; this gave me some thirty points on the glacier-front whose distance and height became known, and thereby the general contour and slope; the latter was found to be 1:3. This, of course, is far in excess of the slope of the glacial stream proper, which is found from our surveys to extend (the western branch) over fifteen miles in in a straight line into the interior and to have a slope of 1:20. It may be mentioned that this branch and the Dawes Glacier emptying into Endicott Arm have the same névé. The mean slope of the Patterson Glacier, lying southeast of the Baird, is in ten miles, 1:13.

The difficulty in using a long base for photographing the face of the glacier is that it is then pretty difficult to recognize many points common to both stations. The photographs were taken on May 15, 19, July 13 and August 11, 1894. The nearest base station (No. 3) was about 900 feet from the ice. The photographs taken from this station show most markedly the change and motion that took place between July 13 and August 11,—twenty-nine days—on which dates views were taken too from station No. 1, 2065 feet from the former. Some fifteen points on the glacier were distinctly recognizable from both stations, and hence plotted in distance and altitude. We had now a fairly accurate delineation of a part of the glacial front so that the distance to any point therein became well enough known to utilize for the purpose to be shortly explained.

It is evident that from photographs from the same station but at different times changes are best seen. A photograph itself, however, only furnishes the angular measurement of any point thereon, both in azimuth and altitude, but not linear measure. Hence, when we are comparing photographs of the same views from the same station, we must know the distances—or

approximately at least — to points under consideration for interpreting properly the changes as shown by the photographs. The glacier having been plotted as already stated, any required distance was obtainable.

A question that suggested itself from the photographs was that of determining the shrinkage or melting of the ice (ablation) between July 13 and August 11, irrespective of any motion. This was obtained in the following manner: On the photographs well-marked points were selected on the adjacent mountains, verticals through which cut the glacier. Each point selected was common to both views. Evidently points which lie in the same vertical plane in one photograph lie in the same plane in another photograph from the same station. There were thus eighteen intersections common to two photographs of the crest of the face of the glacier obtained. We hence had the angular measurement of these intersections, and as the distances thereto were sufficiently well known, the linear measure followed. It is not forgotten that, especially near the face of the glacier, the motion of the ice causes crevasses and upheavals so that in a particular vertical section there may be an abnormal decrease or increase in elevation and the phenomenon of shrinkage obliterated or at least hidden. In fact, the observations or photographs show such to be the case; for in one instance we have a rise of nearly six feet, instead of a decrease of two feet as the average shows. From these eighteen intersections we find that during the twenty-nine days, — July 13 to August 11, — the mass of the glacier — ice front — fell a little over two feet (2.1 feet).

Let us now examine the linear motion of the ice. This problem we can attack from two points — using only photographs from one (nearest — No. 3) station. — Firstly, by finding the vertical motion, and secondly by determining the change in azimuth. The former is directly obtained by measuring on the photographs the distance of a point on the two photographs, above the horizon line, then from its known distance the absolute height in each case is obtained, and the difference will be the motion in altitude for the interval of the photographs. From the general

plotting of the glacier we have its average slope, which in this case is 1:3. From points treated in this way we obtain a mean fall for any particular point during the twenty-nine days of 11.2 feet, being equivalent to a motion of 33.6 feet.

For comparing the azimuths of the same point in two photographs we refer the point in each to the same vertical through some point on the mountains—(the verticals drawn for the purpose of ascertaining the shrinkage were utilized). The linear measure taken on the photographs combined with the fixed focal length of the camera gives the desired angular differences in azimuth, and this latter applied to the known distance of the point gives the motion of the point at right angles to its direction from the station. The quantity expressive of the above motion must be corrected for the actual direction of the point. This latter direction we again obtain from our general plot of the glacier whereon the direction of ridges is established.

For eighteen points change of azimuth was thus determined, and from the relative position of the station to the glacier front the change in the absolute azimuth of a point changed from minus to plus, those to the left or west decreasing, those to the right or east increasing in azimuth, while those directly in front, *i. e.*, where the direction from the station to the point was coincident with the line of motion, showed no change in azimuth. From these we obtain a mean absolute motion of 29 feet, which, combined with the above, gives a mean motion of a fraction over a foot per day from July 13 to August 11. From this data alone it would be imprudent to give an estimate of the total motion in the year. The greatest distance of any point considered was about 3000 feet from the station.

The results obtained may be summarized:

Between July 13 and August 11, 1894, the end of the Baird Glacier was lowered by melting a little over two feet, and the average motion of the ice in that part was one foot per day.

The Baird Glacier consists of two arms, each about 16 miles long. About one-and three-quarters miles from the terminal moraine they merge into one stream. At the western side

emerges a subglacial torrential river, carrying an enormous amount of ground and disintegrated rock—mud. It looks almost too thick to flow. In consequence of its eroding action and the pressure of the moving glacier, its vaulted ice roof near the ice front from time to time collapses, and large masses of ice are then carried out to sea by the rushing waters. Water is found issuing from other parts of the glacier, and not only from underneath but at various points on its face, but only in small streams, and is generally clear or has the characteristic milky color. Although the greater part of the face of the glacier looks "dirty," yet but very few stones are imbedded therein. There is a large quantity of débris on the surface of the glacier, brought down many miles from the eastern arm. The débris is composed of material varying from fine gravel to large bowlders.

An interesting feature of the photographs obtained is the morainic ridge that borders almost continuously the ice front. Its height is about five feet. Examining the photographs of July 13 and August 11, taken from the same station, it is seen that the mounds of which the ridge is composed have changed. This change, like the mounds themselves, is not due to addition of detritus from the face of the glacier, otherwise the accumulation of matter would lie in contact with the ice, which is not the case. The formation of the ridge, and consequently any change thereof, is due to the motion of the toe of the glacier. A side-view photograph taken just beside the glacier makes this apparent.

When we approach the glacier within one or two hundred yards, we meet with depressions in the fluvio-glacial deposit, which increase in depth and sharpness of outline as we advance. The depressions or holes have a maximum depth of about five feet and diameter of about fifteen feet. In a few of the deeper ones a pool of clear water was found. The cause of these depressions is not very apparent. They have not been excavated by streams, but to explain them by the melting of parts of the glacier which projects for some distance underneath the terminal deposit, though plausible, is yet not quite satisfactory.

It would take up too much space to describe in detail our methods of photographic surveying, but a few hints may be suggested to those unfamiliar with the subject and whose explorations and scientific inquiries afford an opportunity for gathering valuable data in the field by means of the camera, which may be subsequently worked out. The first requisite is the utilization of a constant (the principal) focal length for all photographs taken. This necessitates a rigid camera box with no focus adjusting arrangement (bellows). The lens should be a good one, giving a flat image and having an angle of about 60°. To give sharpness to distant points an orange glass screen is always screwed to the front of the lens. This, of course, increases the time of exposure. In the center of each side of the box and in front of the plate is fixed a brass point or comb each of which shows on every photograph and together they serve to orient the photographs. The camera must always be horizontal, to insure which a small level is placed on top; preferably one composed of two in the form of a T. It is convenient to have a foot for the camera so that it can be placed and leveled on the tripod of the transit or theodolite necessary for making the skeleton triangulation, to which the photographs are referred. For good work glass plates are essential. They should be orthochromatic. A convenient size for transport is 4¾ by 6½ inches. In panoramic views, adjoining photographs should have at least one well-recognizable point in common, *i. e.*, the photographs should overlap.

In applying the camera to the study of the motion of glaciers, it is difficult to give definite instructions what to do, as the conditions presented vary so widely. Each case will suggest the most advantageous course to pursue; what length of base to measure; how many pickets to plants across a glacier (it is well to distinguish the pickets by having alternate ones with a "cross-head" T), etc. The photographs want to be taken from the stations, and at intervals of time of a week or weeks, or months, dependent upon the conditions and thoroughness of investigation required. In general we may say that the same

considerations obtain in the selection of photo-topographic stations as for trigonometric stations, *i. e.*, that the intersections for the location of points may be of fairly well conditioned triangles. Every photograph gives — knowing the focal length of the lens — the angular measurement of every point on the photograph, *i. e.*, the azimuth of any point from any other point, and also the angular elevation or depression above or below the horizon of the camera.

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THE CAMBRO-SILURIAN QUESTION IN MISSOURI AND ARKANSAS.

IT is a remarkable fact that of all the great Mississippi basin with its area equal to more than one-third of that of the whole United States, its very center, the portion which is richest and most important of all in mineral wealth, should be the only portion which has remained geologically a veritable *terra incognita*. The region is widely known as the Ozark uplift, a broad dome which occupies the southern half of Missouri and the northern part of Arkansas. The rocks composing it form an important sequence of dolomitic and arenaceous beds which are known to lie between the horizon of the Trenton limestone and the crystalline, or Archæan, complex; and which have recently been termed by Broadhead[1] the Ozark series.

In the earlier geological reports of Missouri great prominence was given to the succession of magnesian beds. By Swallow[2] there were considered to be four thick limestones, separated by sandstones. They were known as the First Magnesian limestone, at top, the First or Saccharoidal sandstone, Second limestone, and so on to the Fourth Magnesian limestone at the bottom. The aggregate thickness of this "Magnesian Limestone" series was considered to be over 1200 feet. It was referred to the Calciferous division of the New York section as then understood.

Since the appearance of Swallow's report other work has been done in the region, and of recent years interest in the subject has been revived. In southeastern Missouri more attention has been directed to the Magnesian rocks than perhaps anywhere else in the Ozark uplift, and although many new facts have been obtained much additional information is necessary before satis-

[1] American Geologist, Vol. VIII, p. 33. Minneapolis, 1891.

[2] Geol. Sur. Missouri, 1st and 2d Ann. Repts., p. 60. Jefferson City, 1855.

factory conclusions concerning the exact geological age of the different parts of the general section can be drawn.

The igneous masses beneath the sedimentaries are known to be Archæan in age. They were subjected to prolonged degradational action; and it was upon their profoundly eroded surface that the sand and limestones were laid down during early Palæozoic times, burying to very considerable depths probably all of the old peaks and elevations. While it is true that the relations of the different sections of the region has not yet been determined with accuracy it appears evident from the data at hand that the Silurian is well represented and that a part belongs to the Cambrian.

In southeastern Missouri the Palæozoic rocks from the top of the column down to the base of the Trenton are well known. Beneath the latter there is, as first made out by Shumard, a bluish, limerock having a thickness of upwards of 100 feet, which has been regarded as the non-fossiliferous portion of the formation just mentioned. Below all this there comes the sequence of dolomites and sandstones to which reference has been made. It has further been stated that there were formerly considered to be four great limestones alternating with arenaceous beds; but of late it has come to be believed that the relations of these beds are not exactly in accordance with the views expressed at first. East of the crystalline area and trending in a broad curve northwest and southeast, a direction which is nearly at right angles to the axis of the uplift, are the oldest Palæozoic rocks whose geological age is definitely known. Immediately west of this belt of strata, which is the fossiliferous Trenton limestone and the band of similar rock but almost without fossils, is a narrow zone of what has been termed the First Magnesian limestone, and then in a somewhat broader belt the First or Saccharoidal sandstone. A short time ago[1] it was suggested that the latter probably rested unconformably upon the strata beneath; and more recently Winslow[2] has reported from the vicinity of

[1] KEYES: Missouri Geol. Sur., Vol. IV, p. 35. Jefferson City, 1894.

[2] Missouri Geol. Sur., Vol. VI, p. 356. Jefferson City, 1895.

Pacific, forty miles west of St. Louis and elsewhere, unmistakable evidences of a marked unconformity at this horizon. Now the Magnesian limestones and sandstones of the crystalline area, are, according to the best accounts, at a geological level considerably below the Saccharoidal sandstone. Regarding the age of the rocks Broadhead,[1] who has been in the region more than any one else perhaps, is inclined to assign a large part of them to the Cambrian. Lately, Walcott[2] in his correlation essay on the Cambrian of North America, has summed up all that is known on the subject and has colored on his map of the continent as Cambrian all of the sedimentaries of the crystalline district of Missouri.

The correlation of the Magnesian limestone of southern Missouri has been almost entirely upon very meager stratigraphical grounds. From one end of the broad uplift to the other, wherever the rocks of this series are open to view, there has been found up to the present time a great paucity of fossil forms. Not only are the rocks almost devoid of the ordinary faunal means by which the different terranes may be determined with precision, but the organic remains thus far secured are so poorly preserved that they are largely worthless for systematic purposes. Further, it is quite remarkable that of all the forms obtained from these rocks there have been none which have been identified with certainty with species described from other districts. In every case where specific comparisons have been made more or less doubt has always been expressed concerning the actual identity of the species referred to. Of the many fossils mentioned in connection with the various allusions to, or descriptions of, the region, few of the references have been more than generic. In a recent critical review[3] of the fossils of Missouri, collections made by different individuals from the Magnesian limestones were examined. The material proved to be so fragmentary on the whole, and the exact or even approximate horizons where the particular forms were obtained so poorly determined that

[1] American Geologist, Vol. III, p. 7. Minneapolis, 1889.

[2] U. S. Geol. Sur., Bulletin 81. Washington, 1891.

[3] Missouri Geol. Sur., Vols. IV and V. Jefferson City, 1894.

practically nothing could be inferred regarding the relations to one another of the fossil-bearing horizons in the different localities. Many of the fossils imperfectly preserved, as most of them were, appeared to be undoubted Silurian forms, while others possessed a very decided Cambrian aspect, but in no case were the faunas extensive enough to warrant an exact arrangement of the succession. All the fossils that have been mentioned or recorded from the limestones of Missouri have recently been tabulated by Winslow & Robertson.[1] By these tables and the accompanying paragraphs of explanation the utterly intrustworthy character of the faunal evidence thus far obtained for separating the Ozark series of Missouri into its proper terranes is admirably shown. Of the total of 151 entries more than one half of the forms are duplicated; only twenty-two are specifically different and of this number but half a dozen are referred to species occurring in other localities. Although considerable information concerning the geology of the district has been obtained there yet remains to be done much detailed work. What is true in regard to the fossils in the strata of this region is equally applicable to those found in other portions of the uplift, except that in most other localities they are of even rarer occurrence.

The Silurian rocks of well determined age which lie above the lower part of Ozark series of Magnesian limestones occur chiefly in the eastern part of the region. They are best exposed along the Mississippi river between St. Louis and the mouth of the Ohio, and include the Trenton limestone, the Hudson shales and certain Upper Silurian limestones. Farther south in northern Arkansas strata thought by Williams[2] to represent a part of this sequence are reported. But it is beneath the Trenton in the eastern portion of the uplift that the difficulty comes in attempting to fix the geological age of the strata.

As explicitly stated elsewhere[3] the Ozark series of Broadhead includes both Silurian and Cambrian, instead of the latter alone,

[1] Missouri Geol. Sur., Vol. VI, pp. 380–385. Jefferson City, 1895.

[2] Arkansas Geol. Sur., Ann. Rep. 1890, p. 108. Little Rock, 1893.

[3] KEYES: Missouri Geol. Sur., Vol. IV. Jefferson City, 1894.

as was finally thought by the author of the name. The limestones of the series cover a very large part of the Ozark region, and it is quite probable that a very considerable proportion of them will be found to be Silurian not only in Missouri but in Arkansas. In the Batesville region Trenton fossils have been recognized by Williams,[1] and beneath the strata containing them are Magnesian limestones and sandstones which are referred to the Calciferous. "Only the upper members, however, are such. The larger part remain to be studied. Below them and exposed to the north is a series which according to Branner pass into Missouri."[2] Farther to the west in the Ouachita district the novaculite rocks are said to be largely Silurian. As evidence a number of Graptolites have been described and a few molluscan remains recognized.

The nearest region presenting rocks of similar age and lithological characters, one which has been, moreover, thoroughly investigated and with which the Missouri strata are to be compared, is in northeastern Iowa and the adjacent portions of adjoining states. It is therefore the Cambro-Silurian section of the Upper Mississippi that must serve as a standard of comparison for the Missouri rocks under consideration, and with which detailed correlations must be made. This fact necessarily has great weight in all attempts to correlate the rocks of the two districts. In the absence of faunal evidence that was at all satisfactory; with so small a proportion, in the Mississippi valley, of the Silurian existing below the Trenton which is an horizon clearly defined in all parts of the basin; with a thickness in Missouri of Magnesian and Saccharoidal sandstone below the Trenton nearly twice as great as in Iowa between that formation and the top of the Cambrian; with the evidence of a marked line of unconformity at the base of the First sandstone; and with a considerable sequence of limestones and sandstones beneath the physical break mentioned, the evidence appeared at the time of the recent review of the geological formations of Missouri amply sufficient for regard-

[1] Arkansas Geol. Sur., Ann. Rep., 1890, Vol. I, p. 112. Little Rock, 1891.

[2] Ibid., p. 116.

ing, provisionally at least, the Magnesian limestone series below the Saccharoidal sandstone as Cambrian. The facts requisite to a final conclusion as to whether or not this line is the correct divisional one must be derived from a consideration of abundant fossils after a careful stratigraphic connection of the various sections has been made. In making a comparison of the Magnesian series with the Cambro-Silurian of Iowa and Minnesota it may be noted that according to the recent work of Hall and Sardeson[1] the line between the Cambrian and Ordovician (Lower Silurian) is carried up to the base of the St. Peter sandstone, where a very distinct faunal break occurs. The Middle Cambrian is also recognized. This narrows down the space between the Cambrian and the Trenton limestone in that region to still smaller dimensions, so that if the inference is correct only a thin sandstone now intervenes. If, further, the correlation by Worthen[2] of the St. Peter formation of northern Illinois and the sandstone at Cap-au-Grès, near the mouth of the Illinois river, and that sandstone with the Saccharoidal of Missouri is right, there is added further weight to the existence of the unconformity at the base of the latter.

Regarding the age and history of the Ozark uplift much might be said. Since it is quite probable that the Archæan peaks of southeastern Missouri formed the first land in the region to appear above the waters of the continental ocean it has been the general opinion among those who have worked in the district that the crystallines remained above sea level as an archipelago from pre-Cambrian times until the close of the Palæozoic when all the area around became a land surface. This has led to the inference that the existing geographic features are very old. But the validity of these conclusions is not only very questionable but it is manifest that the present features of the Ozarks are essentially modern.

It is probable that from Archæan times the region has been one of constant oscillation, for the most part slight, perhaps, but at

[1] Bul. Geol. Soc. America, Vol. VI, p. 170. Rochester, 1865.

[2] Geol. Sur. Illinois, Vol. I, p. 150. Springfield, 1866.

certain periods quite marked. Some of these changes in elevation are clearly defined, but the records of most of them are now obliterated. One of the most notable results of the warping of the lithosphere in this district was at the beginning of Palæozoic time, when the crystalline complex was subjected to profound subaërial erosion. Minor changes of level are also recorded. Another period of notable uprising was during Devonian times. A third was towards the close of the Lower Carboniferous, after the deposition of the St. Louis strata. Still another was one which closed Palæozoic deposition in the continental interior. Unconformities of greater or less prominence record these episodes in the geological history of the region. In post-Palæozoic times the oscillations of level were manifestly not less marked than in the earlier periods. The most noteworthy perhaps was the gain of the land after the protracted submergence recorded by the Cretaceous. It was probably at this time that the forces of compression were felt most and that the warping and folding was more intense than at any other period in the history of crustal movement in the Ozark region. Moreover, it is to this period that the intrusions of igneous rocks along the southern or coastal margin of the uplift in central Arkansas are assigned. Evidences of a subsequent lower level of the land surface are manifested in the peculiarities of the topographic forms in the plateau district and in the relatively uniform evenness of the upland plain. Conclusions deduced from glacial investigations point to a depression in very late geological times of the surface of the continental interior below its present position. This carries with it the inference that since the close of the Tertiary elevation has taken place. This is clearly indicated in the youthful topography now existing along the borders of the uplift. The watercourses have cut profound valleys in the general upland plain, and now flow in canyon-like trenches which are ever deepening as the streams recede from their sources. Erosion is now going on vigorously. The rivers are carrying away the débris from their steep-sided banks as fast as formed, and are rapidly cutting lower and lower their confined and contracted

channels, while their deepening gorges are being constantly carried back towards the crest of the great divide. The cycle of the last movement is not yet ended; and the change in level of the region is probably going on now as rapidly as it ever has in past geological time, and as rapidly as oscillations of the land surface usually take place.

From the foregoing it may be inferred that since the original deposition of the Ozark series, the rocks have been profoundly eroded, and that the later formations which are known to have covered in great part the Magnesian beds of the uplift have been almost entirely removed during the periods of emergence.

As yet, then, the exact geological age of the different parts of the Ozark series is not determined, but the horizons where the proper lines should be drawn are foreshadowed, and with the passage of another season it is believed that the question, both faunally and stratigraphically, will be satisfactorily settled.

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NOTES ON THE EXAMINATION OF A COLLECTION OF INTER-GLACIAL WOOD FROM MUIR GLACIER, ALASKA.

At the solicitation of Mr. Harry Fielding Reid I have undertaken the examination of a small collection of inter-glacial woods obtained by him in the summer of 1892, from the Muir glacier, Glacier Bay, Alaska. These woods were mostly found in place under glacial drift, and there can therefore be no question as to their position.

The buried woods were also accompanied by a number of specimens of living wood from trees found growing at the present time near Sitka. With these living trees were specimens of the leaves that came from them, but unfortunately all the leaves were placed together in a box without numbering, so I had no means of connecting the leaves and wood. The wood has been identified, however, by comparing the internal structure with that of a series of named woods belonging to the Sargent collection obtained for the Tenth Census.[1]

I have also taken the liberty of adding to Mr. Reid's collection a single fine specimen of wood obtained by Miss E. R. Scidmore of Washington, D. C. This specimen, as I am informed by Miss Scidmore, was found protruding from a gravel bank which lay beneath an ice-sheet some seventy feet in thickness, on the eastern moraine of the Muir glacier. As it happens to be the only piece of dicotyledonous wood thus far detected beneath this glacier, it is of particular interest.

LIST OF INTER-GLACIAL WOODS WITH BRIEF MACROSCOPIC DESCRIPTIONS.

1. *From the buried forest, Muir glacier.*

This consists of a single piece six inches long and, approxi-

[1] Tenth Census of the United States, Vol. IX. "The Forest Trees of North America."

mately, an inch in diameter, and several smaller fragments, which all appear to have come from the same trunk. The large piece is slightly worn on one side, but the rest of the specimen appears freshly broken, as do the smaller pieces. This wood is very light and is the most metamorphosed of any of the specimens. It can be easily rubbed to powder between the thumb and fingers, appearing in this respect like wood affected with what is known as "dry-rot." There is no evidence, however, of the presence of attacking fungi, and its softness is doubtless due to its prolonged masceration. It is very dark brown, almost black, in color.

As already stated this specimen has been badly changed, so much in fact that it has been impossible to identify it with satisfaction. It is the only one left undetermined.

2. *From the buried forest, Muir glacier.*

A piece evidently cut from near the root, which is 20^{cm} long and about 40^{cm} in diameter. It is without bark, yet is only slightly abraded. One end is much split and "broomed" as though by action of water. The wood is very hard, and is but little changed.

3. *Found on surface of gravel deposits south of Camp Muir; very abundant.*

A segment cut from a trunk or branch 8^{cm} in diameter. It is without bark and bears evidence of having been exposed. The wood is compact and shows little if any change from the normal condition.

4. *From buried forest, Muir glacier.*

A number of small water-worn branches, the largest being less than 2^{cm} in diameter. The woody structure is very little changed, being still compact and bright where freshly broken.

5. *From buried forest, Muir glacier.*

This consists of two pieces of bark 20^{cm} long and 10^{cm} wide, without trace of wood. This bark, which is less than 1^{cm} in thickness, is but very little abraded and is indistinguishable from recent bark.

5ª. *From buried forest, Muir glacier.*

Consists of a piece of bark 18cm long, 11cm wide and about 4cm thick. It is not the least changed by water action and presents the same bright reddish appearance as a piece from a living tree. It is also accompanied by a number of fragments of wood that are very light, yet appear very little changed. The larger piece is riddled by a number of worm holes, showing that the wood had been exposed for a time to the attack of insect larvæ, before being entombed.

6. *A piece of stump on east side of Muir Inlet, near Camp Muir; uncovered only at very low tide.*

A thin chip, evidently cut from a large stump, having a thin bark still closely attached to it. It has been very little changed by the action of the elements.

A single specimen from under the eastern moraine, obtained by Miss E. R. Scidmore.

This represents a branch or stem 30cm long and about 5cm in diameter. A thin bright-colored bark still adhered to most of the piece, while the wood is very little changed, being bright colored and fresh.

The living woods mentioned above were accompanied by only three kinds of leaves, which have been identified as follows: *Picea Sitchensis*, Carr., *Tsuga Mertensiana*, Carr., and *Chamæcyparis Nutkænsis*, Spach.

PICEA SITCHENSIS, CARR.

The tide-land spruce is a tree of very large size, found from Alaska south to Mendocino county, California, not extending more than fifty miles from the coast. The wood is light, soft, straight-grained, compact and satiny. The bands of summer cells are narrow and inconspicuous, and the resin passages are few and obscure. The medullary rays are numerous and prominent. The color of the wood is light-brown tinged with red, but the sap-wood is nearly white.

To this species I have referred Nos. 2, 3, 4, and 5ª. Of these 5ª is perhaps the most interesting. It has the annual rings clearly marked, the medullary rays in a single series from three

or four to thirty cells high with an average of about twelve or fifteen. The rays in radial section show the walls to be thickened in an irregular manner as represented in Fig. 1. They are provided with a single row of small oblong pits, about two in the width of each wood cell. The wood cells are broad in the sum-

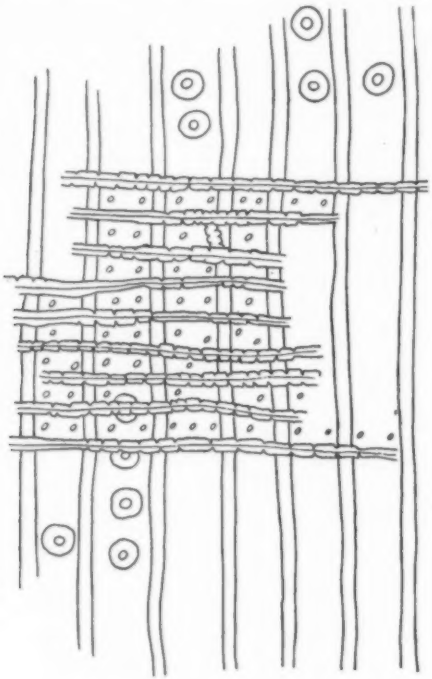

FIG. 1.

mer wood and provided with a single row of contiguous circular pores with a round or oblong inner pore.

This specimen is without doubt the same as that determined by Professor F. H. Herrick[1] who has so accurately described it that it is unnecessary to go further into its description.

[1] Nat'l Geogr. Mag. Vol. IV. 1892, pp. 75–78. Figs. 4, 5.

As stated under the macroscopic description of No. 5^a, it was accompanied by a very thick piece of bark which agrees in every particular with that of the living tree. It is bright-colored and unchanged.

No. 3 is undoubtedly the same as 5^a. It has the medullary rays a little smaller and an occasional resin-duct.

Nos. 2 and 4 do not offer differences of particular account.

TSUGA MERTENSIANA, CARR.

This hemlock is a large tree extending from Alaska south along the islands and coast of British Columbia and thence along the Cascade Range to southern Oregon. The wood is light, hard, close-grained but not strong, with bands of small thin summer cells and numerous prominent medullary rays. In color the wood is light brown, tinged with yellow, with the sap-wood nearly white.

Nos. 5 and 6 are referred to this species. Of No. 6 the small piece submitted has the thin close bark of a branch of hemlock. The medullary rays are two or three to six or eight (or exceptionally twelve) cells high. The annual rings are clearly demarked; the wood cells have a single row of rather small pores with perfectly circular inner pores. In radial section the rays appear simple, that is the walls are straight and not unevenly thickened as in Picea. The walls of the rays have small round pits.

The thin bark (No. 5) described above belongs with little doubt to this species, and I have so regarded it, but in absence of samples of the wood for comparison it cannot be positively stated.

CHAMÆCYPARIS NUTKÆNSIS, SPACH.

The yellow cypress, yellow cedar or Sitka cypress is also a large tree ranging from Sitka south through the Coast Ranges to Oregon. The wood is light, brittle, very close-grained and possesses an agreeable resinous odor. In color the wood is bright, light clear yellow, with thin nearly white sap-wood.

None of the inter-glacial wood obtained by Mr. Reid has appeared to belong to this species, although it is possible that No. 1 may represent it.

ALNUS RUBRA, BONG.

This species, the common alder of the region, is a comparatively large tree with light, soft, close-grained satiny wood, which is light brown tinged with red in color, the sap-wood being nearly white.

The specimen described above that was obtained by Miss Scidmore, is referred without hesitation to this species. It is so little changed that it might be mistaken for a recently grown example.

F. H. KNOWLTON.

U. S. Geological Survey.

LAKE PASSAIC—AN EXTINCT GLACIAL LAKE.[1]

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LAKE PASSAIC is the name given by Professor Cook in 1880 to an extinct glacial lake supposed to have existed in northern New Jersey during the last glacial epoch. Although the existence of

[1] GEO. H. COOK. Annual Report of the State Geologist of New Jersey, 1880; pp. 61–64. ROLLIN D. SALISBURY. Ibid., 1892; pp. 126–144. ROLLIN D. SALISBURY and HENRY B. KÜMMEL. Ibid., 1893; pp. 225–328. HENRY B. KÜMMEL. Thesis for the Degree of Doctor of Philosophy, University of Chicago, July 1895 (In Press).

the lake has been called into question, recent work has shown that Professor Cook was right in his main conclusion, although he was not in possession of the large body of facts which together demonstrate that conclusion. The lake occupied the basin-like area between the curving trap ridges, known as the Watchung or Orange mountains on the southeast, and the gneissic highlands on the northwest. Its northeastern end was in the vicinity of Little Falls, and its southwestern near Liberty Corner.

The basin is now drained in a roundabout way by the Passaic river, which finally escapes across the Watchung mountains at Little Falls and Paterson. Of the Watchung mountains it was the Second which formed the rim of the basin in which the lake lay.

The height of the Passaic river where it crosses this mountain at Little Falls is 158 feet. During the life of Lake Passaic, this outlet, as well as the valley now occupied by the Pompton river was choked by glacier ice. Leaving the Pompton valley and the Little Falls Pass out of account, there is no other break in the rim of the lake basin lower than 331 feet. At this altitude there is a pass across the enclosing trap ridge at Moggy Hollow, about two miles west of Liberty Corner, at the southwestern end of the basin. This outlet regulated the level of the lake for a considerable period of its history.

Within the area of the lake there are several trap ridges, of which Long Hill, extending from Chatham to Basking Ridge, is the most important. Its general course corresponds with the longest diameter of the lake. The lake basin is divided in the direction of its shortest diameter into two nearly equal parts by the terminal moraine between Chatham and Morristown.

The record of itself, which Lake Passaic left, consists principally of (*a*) shore features, (*b*) berg deposits, (*c*) lacustrine deposits, (*d*) a slight difference in the nature of the till within the lake basin and of that without. Most reliance is placed upon the shore features, but the other lines of evidence have much corroborative weight.

THE SHORE FEATURES OF LAKE PASSAIC.

The shore features of Lake Passaic are not conspicuously developed, and their obscurity is plainly not the result of subsequent erosion. It follows that they were never well developed. Since the size of the lake was sufficient for waves of several miles fetch, the meager development of shore features cannot be ascribed to the smallness of the lake. Since the conditions for the development of shore features seem to have been favorable at many points, their local absence and their general indistinctness is not to be explained on the basis of unfavorable conditions. We are left to conclude, therefore, that the meager development of shore features about the border of the lake is due to its shortness of life. In spite of the general fact expressed in the statements above, shore features are locally pronounced enough to be unmistakable.

The distribution of the shore features seems to be somewhat fortuitous. They are absent from some localities where their presence was to have been expected, and they are sometimes well developed where there seems to be good reason for their exceptional distinctness.

Shore features of the extra-morainic basin. A. Degradational forms.—Wave-cut terraces and lake cliffs are but poorly developed. In numerous localities, ill-defined terraces have been observed at about the level of the lake, some of which, as shown by their close connection with constructional forms, are probably of lacustrine origin. The best marked of these are upon Long Hill. At its north end, half a mile south by west of the Chatham depot (see map), there is a distinctly marked cliff and terrace. The cliff rises by a steep slope from the terrace, at the upper edge of which there are a number of drift bowlders apparently washed out of the till in which the cliff is cut. At several points on the terrace the trap rock is exposed, indicating that the terrace was formed by erosion, not by deposition. The upper edge of the terrace has an altitude of 369 feet, and is sharply defined. This wave-cut terrace can be traced southward along the eastern side of Long Hill. Its surface there becomes

sandy, and it soon passes into the wave-built terrace to be seen in the lower part of the Chatham cemetery. The clearly defined cliff above the bowlder-strewn cut terrace, and the graduation of the latter into the distinct wave-built terrace, make this one of the best marked features of the extra-morainic basin.

Along the southeastern or front face of Long Hill, narrow terraces with steep rock slopes above may be observed in several places. Probably not all of them, and perhaps none of them, are to be ascribed wholly to the lake. Some of them may be benches and cliffs of differential degradation, due to the contrast in hardness between the trap and the underlying Triassic sandstone, which here and there have their junction at or near the lake level. This, however, will not account for all of them. Northwest of New Providence there is a distinctly marked bench in the sandstone, at an elevation of 367 to 369 feet. It can be traced almost continuously into a well-marked spit a mile west of New Providence. Because of this connection, especially, its reference to the lake seems proper.

Near the outlet at Moggy Hollow, a mile and a half west by north of Liberty Corner, there are slight traces of wave cutting. The phenomena are such as would be produced on a gently sloping, rocky shore against which the waves had beaten but a short time, and where the finest material had been carried away, leaving the ill-rounded pebbles where they originated. Both above and below the zone thus affected, the rock is covered by a much deeper layer of residuary soil. The height of the mean lake level at this point, as shown by other evidence, was between 351 and 356 feet.

After everything possible has been said in favor of the lacustrine origin of the terraces and cliffs found around the lake basin, it must be admitted that, were the proof of the existence of the lake dependent upon them alone, its existence could not be stoutly maintained. There is not a terrace in the extra-morainic part of the basin, the wave-cut character of which, taken by itself, can be said to be beyond question.

B. Constructional forms. 1. *On the trap, shale and gneiss*

LEGEND
TRIASSIC ISLANDS
MORAINE ISLANDS
SHORE GRAVEL DEPOSITS
SUBAQUEOUS OVERWASH PLAINS AND GLACIAL DELTAS
POSSIBLE WAVE CUT CLIFFS AND TERRACES
POMPTON PLAINS
JACKSONVILLE
MONTVILLE
BOONTON
GREAT PIECE MEADOWS
LITTLE FALLS
TROY MEADOWS
CALDWELL
HANOVER
MADISON
NEW VERNON
CHATHAM
SHORT HILLS
STANLEY
SUMMIT
GREAT SWAMP
NEW PROVIDENCE
MILLINGTON
MAP OF LAKE PASSAIC
1 2 3 4 5
MILES

slopes.—The constructional forms are more distinct. In a number of localities there are small but distinct spits, bars, and constructional terraces, whose heights are closely accordant one with another. In many more localities, on the slope of the lake basin, or on the slopes of the islands which stood in it, there are beds of stratified, poorly rounded, but nevertheless distinctly water-worn gravel of strictly local origin.

Although not possessing distinct topographic form, these beds of local gravel agree in height, material, and structure with the well defined constructional terraces at other points. Where the gravel is not present in beds, scattered water-worn pebbles of local origin have been found at numerous places at levels corresponding with those of the well defined shore features. So general is their presence, as to warrant the belief that the shore gravel is much more nearly continuous about the former margin of the lake than superficial inspection would indicate. Nowhere have constructional shore features, beds of local gravel, or scattered water-worn pebbles of local origin been found about the lake basin, or on the islands in the lake, above the level at which the waters of the lake could have been confined.

On Second mountain well-defined beds of local gravel have been found at thirteen points. The location and the height of the more important of these is shown on the accompanying map. With one exception they range in altitude from 344 to 369 feet A. T., while single beds have a vertical range of as much as fourteen feet. A single bed of gravel is known at a lower level—about 300 feet. On the gneiss highlands between Bernardsville and Morristown, two small deposits of wave-worn gneiss pebbles are known at elevations of 371 feet to 380 feet.

During the life of the lake, the cols of the ridge known as Long Hill were straits. At the same time, the crests above the cols constituted islands. Of these there was a series of nine. They were long and narrow, and rose above the water to heights not exceeding 125 feet. Débris carried by the waves and currents along the shores of these islands, accumulated at their ends,

(in or near the present cols) as spits, bars, or beds of gravel and sand. Considerable beds of trap gravel occur in four of the cols. Water-worn trap pebbles in lesser quantity are found in all the others at accordant heights. Between the cols along the shores of the former islands, there are frequent traces of gravel identical with that of the cols at corresponding heights. Such gravel is probably more widespread and greater in quantity than is now shown, since exposures are few. Such as exist are often most insignificant. Thus on the northern slope of Long Hill, one and three-fourths miles west of New Providence, a shallow, freshly-dug trench several hundred feet in length was seen (1893). Its course was across the shore line. On the surface there was no topographical evidence of wave action, nor were the water-worn pebbles abundant enough to attract attention. Above an elevation of 361 feet, the material exposed in the trench was material which had arisen from the decay of the trap rock. Below 361 feet the trap residuary was succeeded lakeward by coarse, wave-worn trap pebbles. The gravel was roughly stratified, and contained occasional foreign pebbles. Further down the slope the gravel was succeeded by sand, and that again by gravel. A thin layer of clayey loam, the result of post-lacustrine wash from the slopes above covered the whole. This exposure proved conclusively that some agent had been at work on the lower slope, re-working and re-arranging the local material up to a certain definite level, above which it did not reach. The element of height appeared to be the only controlling factor. Waves could produce the observed phenomena; running water could not. This significant exposure showed that the absence in some localities of topographic shore features, and of rounded surface gravel, does not militate against the lake hypothesis.

In addition to the beds of gravel on Second mountain and Long Hill, similar deposits occur at the proper heights upon the hills near New Vernon and south of Morristown.

A few of the constructional shore features deserve separate mention. (*a*) In the lower part of the cemetery of Chatham, there is a high, well marked, wave-built terrace of sand and

gravel, to which reference has already been made. It is composed of glacial gravel, derived from the till which covers this end of Long Hill. The elevation of its upper edge is 369 feet A. T. (*b*) A wave-built terrace of trap gravel, 100 to 150 yards wide, is found just north of Lyons Station, at the southern end of what was a peninsula. Northward from this terrace along the shore line rounded pebbles of local origin occur in considerable numbers. As the red shale rises to the lake level at Basking Ridge the shale pebbles become more abundant in the shore gravels, while the trap pebbles become proportionally less. (*c*) Southwest of Moore's hotel, Basking Ridge, where the old shore line has an elevation of about 367 feet, there is a broad wave-built terrace at the head of what was a small bay. The gravel of which it is composed is chiefly from the local shale. (*d*) Near the sag in Long Hill, a mile and a quarter west of New Providence, there is a short but pronounced spit. Northeastward it is continuous with what may be a wave-cut terrace, as elsewhere noted. The gravel is chiefly of red shale, derived from the subjacent terrane. In cross-section the lines of bedding are seen to dip outward, forming what may be called anticlinal stratification. (*e*) Another short spit occurs about three-quarters of a mile west by north of Berkeley Station. Its elevation is somewhat (45–50 feet) less than the maximum level of the lake.

The composition of these gravel beds, considered in relation to the underlying and adjacent indurated formations, is most significant. On Second mountain—a great trap ridge—the gravel deposits attributed to shore action are composed almost wholly of fragments or pebbles of trap, with only occasional foreign pebbles. The same is true, in the main, of Long Hill, though on the south side of this ridge the red shale occasionally rises to the level of the lake. Where gravel beds are found on shale slopes instead of trap, shale has made the principal contribution. The spit west of New Providence is an instance in point. Where the shore of the lake was against a drift-covered slope the gravel beds are composed of drift gravel. The terrace in the cemetery

of Chatham is an illustration. In the vicinity of Basking Ridge, deposits of trap gravel grade into those of shale where the shore line passed from the trap to the shale. Along the gneiss highlands the two gravel beds known along the margin of the lake, are largely of gneissic gravel and sand, and local sources for the other constituents are at hand. Near New Vernon the gravel deposits on the trap hills are mainly of trap, those on the shale are composed chiefly of shale, while those on the Triassic conglomerate are of quartzite pebbles, derived from the conglomerate itself. The foreign pebbles in the shore gravels may belong (*a*) to the older drift, remnants of which occur at various points about the lake; or (*b*) they may have been transported along the shore of the lake from the newer drift; or (*c*) they may have been carried to the shore of the lake by blocks of floating ice, starting from the moraine.

Waves and shore currents are the only known agencies which can develop water-worn, stratified gravel, sustaining this definite relationship to the adjacent and subjacent formations. The topographic situation of some of these shore deposits of gravel, taken in connection with their composition, is such as to admit of no second interpretation. Generally speaking, they occur along a horizontal belt at a definite elevation, either (*a*) on the slopes of higher lands, or (*b*) in the passes and cols between them. Above this definite level, gravel such as described does not occur. Below this level, such beds of gravel occur as might have been formed during the later stages of the lake's history, when its level was sinking and its area diminishing.

A careful study of the shore deposits, particularly their relations to headlands of rock and wave-cut benches, gives us some knowledge of the general direction of the waves and shore currents. On Long Hill the shore drift traveled, in general, southwestward, as shown by the terrace near Chatham, the spit west of New Providence, and the spit west of Berkeley station. Near Basking Ridge the material was carried southward, as shown by the shale gravel southwest of Moore's hotel, and the trap gravel at the south end of the ridge near Lyons. Three different

deposits on the hills a mile and a half south of Morristown were clearly formed by westward moving currents.

Three particularly favorable classes of localities for the deposition of the shore gravels can be made out. These are (*a*) in the shallow, narrow straits between islands, the numerous deposits along Long Hill being the most marked examples; (*b*) at the ends of the islands or peninsulas where the shore currents (1) kept their course as the island was passed, spits being the result, the spit near New Providence being a good example; or (2) where the shore currents lost their velocity by spreading, in which event terraces were formed, the terrace just north of Lyons being an example; (*c*) at the heads of small converging bays, the terraces west of Basking Ridge and east of Bernardsville being good examples.

2. *On the outer face of the moraine.*—In addition to the constructural shore features already described, there are still others in the extra-morainic part of the basin which testify in no doubtful way to the former existence of Lake Passaic. The outer face of the terminal moraine, in so far as it lies in the lake basin, is bordered by a subaqueous overwash plain[1] of goodly proportions. The special characteristics of deltas and subaqueous overwash plains are flat tops, sloping gently from the head to the front, a steep front slope (indicated by hachures on the map), a lobate margin with deep re-entrant angles and projecting cusps, and a tripartite structure, as seen in vertical section. This structure consists of (*a*) nearly horizontal beds at the top, underlain (*b*) by beds dipping steeply towards the front, and these in turn rest upon (*c*) horizontal or nearly horizontal layers of fine material. All these features are illustrated by the plains bordering the moraine on its outer face. Thus near West Summit there are three prominent marginal lobes on the subaqueous overwash plain. West of Madison, the flat top of the plain is a third of a mile wide, with a fall of about ten feet in this distance, whereas its steep front falls off 60 feet in 100 to 200 yards. Southwest

[1] An overwash plain made in standing water. See Annual Report of the State Geologist of New Jersey, 1892, p. 41.

of Convent station the top of the plain is half a mile wide. From its upper edge at the moraine it slopes gently to the southwest, declining 20 to 25 feet in the half mile. Here it falls off abruptly, with a slope which declines about 50 feet in 125 to 150 yards. While no single exposure was found which showed the complete tripartite structure, exposures were seen which showed the several beds individually, and there can be little doubt that good exposures would reveal the three in vertical section.

The line marking the junction of the gently sloping upper surface of the plain, with its abrupt front, marks the approximate water level at the time the plain was finished. But when it is desired to fix the water level exactly, or even within two or three feet, many inconsistencies seem to be involved if it be assumed that the line marking the change of slope corresponds accurately with the water level. There are several reasons for believing that it does not. (*a*) It has been found that even where the change of slope is most marked and can be accurately fixed, its height varies three, five, or even seven feet within comparatively short distances. (*b*) A consideration of the manner in which glacial delta plains are formed shows that the pronounced change of slope must mark the point where the bottom current of the running water which was rolling the débris, so far lost its velocity that its load was dropped. It would seem, therefore, that the upper edge of the steep slope cannot be built nearer the surface of the lake than the depth of the current which, at that particular point, is supplying detritus. Since the depth and velocity of the various streams supplying detritus were different, and since a subaqueous overwash plain was built by a number of streams or by the distributaries from a single stream, all of which have various depths and velocities, the upper limit of the frontal slope should be of varying heights on adjoining lobes, and might even vary to some extent on the same lobe. We conclude, therefore, that the lake level was somewhat (perhaps sometimes several feet) higher than the upper edge of the highest "fronts," and that the water covered the outer and lower part of the gently

sloping top. The depth of the submergence at different points would depend upon local conditions.

From data supplied by the other shore features, it seems probable that west of Madison, the lake shore corresponded approximately with the present elevation of 373 feet, covering nearly all of the plain whose outer edge has an altitude of 362–5 feet; that west of Convent the shore corresponded approximately with the present level of 374 feet, the outermost lower edge of the plain having an altitude of 356 to 364 feet, and the upper edge of 382 feet; and that at West Summit the former water level has a present elevation of 367 feet, whereas at this point the outer edge of the plain has an elevation of only 345 to 356 feet, rising to about 380 feet at its moraine edge. It is perhaps not necessary to suppose that the edge of the plain was developed contemporaneously at these several points, or that the level of the lake was absolutely constant.

The subaqueous overwash plain bordering the moraine is a very considerable one. Since deposits of this sort may be of very rapid construction, a long period is not demanded for its growth.

SHORE FEATURES OF THE INTRA-MORAINIC BASIN.

The shore features of the intra-morainic portion of the basin differ in several important respects from those of the extra-morainic basin. These differences are due to the different conditions which prevailed in the two parts of the basin. The intra-morainic part of the basin was occupied by ice for a portion of lacustrine time. Its lake history, therefore, must have been briefer than that of the extra-morainic portion. In so far as it was briefer, its shore features should be less strongly developed than those of the extra-morainic portion of the lake. On the other hand, since the glacier left thick deposits of sand, gravel, and till upon which the waves could readily work, and since an enormous amount of loose material was furnished to the lake directly by the melting ice, constructional terraces, spits, bars, etc., could have been rapidly built under these favoring con-

ditions. The abundant supply of shore and glacial-stream drift might even more than compensate for the shorter life of this part of the lake. It is to be remarked that deposits of water-worn gravel in this part of the lake must possess the structure and topographic forms characteristic of shore deposits. Otherwise they are no proof of the existence of the lake, since streams from the melting ice might form beds of gravel at any elevation, within or without the lake basin.

Degradational features.—Within the intra-morainic basin, there are no terraces which can be asserted to be wave-cut. On the inner face of the moraine, between Chatham and Littleton, there are discontinuous, often bowlder-strewn terraces in the drift, sometimes limited above by steep cliff-like slopes. They may be of lacustrine origin. On the east shore of the lake between Summit and Caldwell, particularly east and southeast of Livingston, benches have been observed, which resemble wave-cut terraces in some respects. Similar benches occur at one or two other points. In themselves these terraces would be an insufficient basis for affirming the existence of a lake in the intra-morainic part of the Passaic basin. They may, however, have some corroborative significance.

Constructional features.—The chief constructional shore features of this part of the basin are deltas, built in immediate juxtaposition to the ice, by heavily laden glacial streams. Under such conditions the supply of material was great and the growth of the deltas rapid, resulting in the production of very considerable plains in a comparatively brief time. The deltas are numerous and decisive in character. They occur in greater numbers, and in better development on the west and northwest sides of the lake, than along its eastern shore. The most important of them are represented on the map, their steep fronts being shown by hachures.

A mile north of Parsippany, there is a gently sloping, slightly undulatory plain of sand and gravel, having an area of a quarter of a square mile. It has the lobate margin, steep front, and re-entrant angles characteristic of deltas. Its lobes rise

thirty feet above the lower land to the south and west. Northward, the plain passes into an irregular kame area, which it is believed marks the site of the ice edge during the formation of the delta. The water level corresponded to the present elevation of 394 or 395 feet.

Between Boonton and Montville, southeast of the canal, there is another glacial delta having an average width of half a mile or less, and a length of two miles. Towards the upper limit of the plain, bowlders are numerous, and the surface somewhat irregular. Patches of till are also present, apparently indicating that the ice lay on the higher ground to the northwest during the formation of the plain. The general level of this plain is less than 400 feet. Along much of the front of this delta, there is a lower terrace marking a stage of the lake 70 to 75 feet below the maximum stage.

Just north of Montville there is a perfect example of a glacial delta, having an area of about a quarter of a square mile. The top slopes gently from north to south, and then falls off abruptly for 70 to 90 feet. Its margin or front is distinctly lobate. The water level here seems to have been along a line which now has an elevation of 397 to 398 feet.

A mile and three-quarters north of Whitehall, and west of the Jacksonville schoolhouse, there is another small delta, whose frontal lobes are well marked. This deposit indicates a shore-line having an elevation of 408 to 410 feet.

The largest and most typical delta of Lake Passaic occurs at Upper Preakness. Its surface is nearly flat. Its margin is strongly lobate, falling off abruptly 50 feet. Its area is about one square mile. Its elevation, 335 to 340 feet, indicates a lake stage about 70 feet below the maximum in this region. It is to be correlated with the lower terrace on the Boonton delta. Just north of this plain is a moraine-like kame belt, half a mile in width. The hillocks are of coarse material, and are often thickly strewn with bowlders. At the same time that the Upper Preakness delta was building, the kame belt was probably formed just beneath the ice and at its irregular margin.

North of the kame belt is another but more irregular plain of sand and gravel, the surface of which seems to have been more or less modified, by the action of standing water. To have extended over it, Lake Passaic must have covered a surface which now has an elevation of 412 feet.

A mile and a half west of Haledon, near Paterson, there are delta-like terraces at two levels. They mark water levels which now stand at 412 feet, and 340 feet respectively. In the vicinity of Caldwell, also, there is a somewhat extensive sand and gravel plain, which has a similar significance.

Of the glacial deltas and terraces, those (*a*) at Montville, (*b*) west of Jacksonville, and (*c*) at Upper Preakness, are the most typical. The northern margins of the two last named have the irregular, hummocky surfaces characteristic of gravel beds, which were originally built against the ice, but which have since slipped and fallen down as the ice melted. In places the slopes still retain the irregularities of the ice mold in which they were cast. Several of the other plains pass into kame areas, which are believed to have been formed beneath the ice and at its irregular edge and to mark the position of the ice front, at the time of the formation of the deltas. In a number of cases, kames of an older generation have been partially buried by the advancing front of the growing deltas.

In addition to the deltas, there are a few small spits connected with what appear to be wave-cut terraces, and a few kames whose summits seem to have been truncated by the waves; but aside from the glacial deltas, the constructional shore forms are not conspicuous or decisive. The largest deltas within the moraine may have required far less time for their building, than the gravel beds along the trap ridges in the extra-morainic part of the lake.

THE LACUSTRINE DEPOSITS OF LAKE PASSAIC.

Iceberg deposits.— Iceberg deposits in the extra-morainic part of the lake basin consist mainly of bowlders similar to those of the moraine. They are found frequently up to altitudes of 340 feet, and more rarely up to the maximum level of the lake. Although

distributed widely over the area of the basin, they are particularly conspicuous on the low land in the immediate vicinity of Moggy Hollow outlet.

Bowlders of granite, gneiss, quartzite, and conglomerate are found at some points above the probable shore-line on the trap ridges. As compared to the bowlders of corresponding material below the shore-line, their greater age is shown by their greater decomposition. They are regarded as remnants of a pre-morainic sheet of drift.

North of the moraine, iceberg deposits cannot be differentiated with any degree of certainty from the deposits formed directly by glacier ice.

Clays and silts.—Clays and silts, which are believed to be lacustrine, are very generally present over the low areas of the extra-morainic basin. They underlie all the area of the Great Swamp and its immediate surroundings. Within this area they do not occur above an altitude of 240 feet. Somewhat similar clay has been found in a few places at higher levels, but always much below the highest shore-line. The clay of the eastern half of this area is covered with fine, sandy loam, which, as the moraine is approached, grades into sand and gravel. Though more or less buried by stratified drift, clay also occurs south of Morristown, southwest of Convent, and southwest of Madison. These relationships show that the lacustrine clay passes under, and therefore antedates the moraine and its contemporaneous overwash plain. The upper part of the clay may represent the bottom-set beds of the extra-moraine stratified drift.

In the Great Swamp area the clay attains great thickness. Wells 25 or 35 feet deep do not pass through it. A mile and a half south of Green Village it was penetrated to a depth of more than 100 feet, although there is no positive evidence that all this deposit is lacustrine. The lacustrine clay is "fat" or "greasy," and a little below the surface is finely laminated, the laminæ of clay being separated by fine partings of a more sandy nature. It is highly calcareous, and frequently contains concretions of

carbonate of lime. These concretions are very abundant at certain horizons, in various localities.

Clays which are of the lacustrine type have been found at several localities in the intra-morainic portion of the basin. They are similar in general appearance to those outside of the moraine. They are generally at low levels, and in places are associated with clays which may be post-glacial in origin. In some places this clay is covered by till. Where this is true, the relations suggest either (*a*) that the clay belongs to an early period of the lake's history, if it be lacustrine at all, or (*b*) the till over it is berg till, or (*c*) till deposited by the ice during a temporary re-advance in the general period of its treat.

The till of the intra-morainic part of the basin.—Much of the till of the intra-morainic part of the lake basin is not of the normal type. This abnormal phase is stony, but not gritty. On the contrary, it is very clayey. It has a more or less greasy feeling, a waxy or glazed surface when cut, and a pronounced tendency to crack on drying. Many of the pebbles are coated with a thin film of clay, which is not easily removed. The color is dark red, tinged with brown. This type of till occurs most commonly at low levels. It has nowhere been found up to the level of the shore-line. Normal till is not uncommon within the lake basin, and it sometimes occurs in close proximity to the type noted above.

It is not possible to say to what extent this abnormal type of till was formed beneath the ice, and afterwards submerged, and to what extent it was formed beneath water by icebergs floating on the lake. A somewhat similar, waxy, clayey character affects much of the soil on the red shale in the extra-morainic part of the basin, a characteristic foreign to unmodified red shale residuary.

THE OUTLETS OF LAKE PASSAIC.

The Moggy Hollow outlet.—A mile and a half west by north of Liberty Corner, at Moggy Hollow, there is the notch in the rim of the basin, through which Lake Passaic drained during its maximum stage. The bottom of the notch has an altitude of 331

feet, and with the exception of the gaps at Little Falls and Paterson and the low ground along the Pompton river, all of which were closed by the ice when the lake existed, this is the lowest point in the rim of the basin. The notch is a flat-bottomed, steep-sided trench, 60 yards wide at the bottom and 157 yards wide at the height of the maximum lake level. It is cut in hard trap rock, which outcrops at many points on the sides and bottom of the trench. Its form is altogether conclusive that it was the channel through which flowed a stream of water, whose average width was about 150 yards, and whose depth was sufficient to give it great velocity. In pre-lacustrine times there may have been a col on the site of the notch, but the notch in its present form is due largely to erosion by the outflowing current of the lake. Through this outlet the drainage of the lake entered the North Branch of the Raritan.

The Millington gorge.—The Passaic river escapes from the area of the Great swamp by a deep narrow gorge through Long Hill, at Millington. The gorge is 60 to 70 feet deep, very steep sided, and, so far as shape is an index, seems to be of very recent origin. So young does it appear, that the hypothesis was for a time entertained, that it was largely or wholly post-glacial. This hypothesis was finally abandoned because of the small amount of trap gravel in the valley below the gorge (too little by far to fill it), and because of the evidence afforded by the Stanley gorge, as to the amount of post-glacial cutting by the Passaic. This evidence is cited below.

The Stanley outlet.—Near Stanley, the Passaic river has cut a passage through a drift barrier in post-lacustrine times. The amount of post-glacial cutting is here 25 to 30 feet of which 18 feet is in drift, the remainder in red shale. The passage which the river has cut here is much wider, much less steep-sided, and less deep than the gorge at Millington. The differences in width and slope may well be due to the differences in the hardness of the material. The difference in depth between the post-glacial cut at Stanley, and the gorge at Millington is most significant. All conditions seem to favor erosion at Stanley, as compared

with Millington:—(*a*) the size of the stream is greater at Stanley; (*b*) its gradient is slightly greater; and (*c*) the material in which it has cut is very much more easily eroded. If, under these circumstances, the post-glacial cutting at Stanley has been no more than the figure cited above, the amount of post-lacustrine erosion at Millington gorge must have been much less.

Before being lowered by erosion, the drift dam at Stanley had an elevation of about 230 feet. After the ice freed the Little Falls-Paterson outlet, a long, narrow lake must have had a temporary existence behind this barrier, in the valley between Second mountain and Long Hill. Its greatest depth could hardly have exceeded twenty feet. All the lacustrine clay between Long Hill and Second mountain lies below this level, and furthermore most of the surface below this level is clay-covered. There is little doubt that such a lake existed for a time after the great body of the water of Lake Passaic had drained away. It was lowered as the Stanley gorge was cut down, and disappeared when the outlet was cut to the level of its bottom.

The Little Falls outlet.—Where it is crossed by the Passaic river at Little Falls, Second mountain is broken by a gap more than two miles wide. The bottom of this gap is nearly flat, and is covered with a coating of till, clay and fine sand, not exceeding ten feet in depth, where now cut through by the river. It is certain that the level of the outlet which Lake Passaic found via Little Falls after the retreat of the ice, had an altitude of not more than 190 feet, and not less than 175.

At West Paterson, the Passaic river crosses First mountain through a gap two miles wide. When the ice had melted back so far as to open this outlet, the river must have crossed this ridge at an elevation of not more than 150 feet, and not less than 125 feet. Since this height is at least 12 feet lower than the height of the lowest swamps in the lake basin, this rocky barrier could not have caused subordinate lakes within the Passaic basin.

Great Notch.—Three miles south of Paterson, First mountain

is cut by a narrow gap, whose bottom is 303 A. T. Under certain conditions this gap might have served as an outlet for a brief period. Examination of the gap failed to reveal data which could be regarded as proving either that the lake did or did not drain through it at any time.

The drift-filled gap at Short Hills.—West of Short Hills the crest of Second mountain is broken by a sag whose bottom has an elevation of 380 feet, an elevation 170 to 200 feet lower than the average height of the trap crest of the mountain. The terminal moraine crosses Second mountain through this sag. Some years since a deep well was bored just below the summit of this sag at an elevation of 370 feet. The well was sunk 200 feet *without reaching the trap rock*. The rock bottom of this gap, therefore, must be below 170 feet A. T. There is good reason to believe that it is much below this figure. A quarter of a mile east of the Short Hills depot, at an elevation of 200 feet, there is a well 200 feet deep. At this depth, that is at sea level, rock was reached. This well is located in the shale valley between First and Second mountains, and is in line with the gaps in Second mountain west of Short Hills, and in First mountain at Millburn. These facts and relations clearly indicate a deeply buried channel across Second mountain at Short Hills, and across First mountain at Millburn, the rock bottom of which at one point between the two trap ridges, is known to be at sea level. If the rock bottom at the gap in Second mountain be no lower than 170 feet—the bottom of the boring—the preglacial stream must have had a fall of 170 feet on the south face of Second mountain. The width of the gap is such as negative this conclusion. It is so great as to indicate that the stream which occupied it was of considerable age. It is probable, therefore, that the bottom of the rock gap in Second mountain is very much lower than 170 feet, the height at which the boring ceased.

It follows, therefore, that the main drainage of the Upper Passaic basin in preglacial times was almost certainly through the Short Hills and Millburn gaps. Manifestly Lake Passaic

could not have come into existence until the first of these gaps was closed by the ice and drift.

THE HISTORY OF LAKE PASSAIC.

Something can be inferred as to the preglacial drainage of the lake basin from the gaps in its rim. Through the lowest gap, that at Short Hills and Millburn, the larger part of the preglacial drainage of the Passaic basin doubtless escaped. It is probable that another stream of less size, draining the northeastern part of the Passaic basin, flowed through the gaps at Little Falls and Paterson. The drainage areas of these two basins could have been separated by no more than a low divide, as shown by the present topography.

The advance of the ice.—When the ice sheet closed the gap at Little Falls, the drainage must have accumulated in front of the ice in the northern basin referred to above. Any lake which may have been formed at this time must have been small and shallow, for it must soon have overflowed the low divide which separated the drainage basin having its outlet at Little Falls, from that which had its outlet through the Short Hills gap. As the ice advanced, it encroached upon this hypothetical lake, displacing its water and diminishing its area and finally destroying it altogether.

No lake could have been formed in the drainage area of the river which flowed through the Short Hills gap, until after the ice reached that gap and filled it. Then, and not until then, could a lake have existed in the basin south of Morristown. So soon as this gap was closed, water from the melting ice began to accumulate in that part of the basin which the ice did not fill. This was the beginning of Lake Passaic. The water rose until it reached the level of the Moggy Hollow outlet, through which it drained. As already stated, the bottom of the notch in the rim of the lake basin at this point, is 331 feet above tide. During the period when this notch served as the outlet, erosion is believed to have lowered it not more than 25 feet.

The Madison stage.—When the ice had blocked the Short

Hills gap, Lake Passaic began its existence. Since the ice of the last epoch had then reached its maximum extension, the area of the lake was at a minimum. The lake seems to have remained at approximately the same level during the time when the moraine and the subaqueous overwash plain which borders it were formed. During this period of maximum level there were formed, in part at least, the high-level shore lines in the extra-morainic basin. To this stage belong the broad, subaqueous overwash plain extending from Chatham to Morristown, and perhaps also the somewhat lower plains near West Summit, the gravel deposits near Bernardsville, Basking Ridge, Lyons, Millington, New Providence and New Vernon, as well as others of less importance. This stage of the lake may be called the Madison stage, from the fine development of the subaqueous overwash plain west of that place. During this period there were doubtless minor oscillations of the water level, due chiefly to varying rates of melting of the ice. Such oscillations of level may perhaps explain some of the minor inequalities in the heights of the different lobes of the subaqueous overwash plain.

The retreat of the ice.—As the ice melted back from the moraine, the lake increased in area by successively filling those parts of the basin from which the glacier withdrew. During this period, the lake must have been more or less completely divided into two parts by the moraine, which, for part of its course across the basin, rises above the maximum water level. This barrier did much to prevent débris-bearing icebergs from reaching the extra-morainic basin, and thus limited the time, during which berg deposits could be made outside the moraine, to the period of ice advance.

During the retreat of the ice, an embayment of several miles affected the front of the glacier, where it crossed the basin of the lake. The glacial deltas between Boonton and Parsippany, southeast of Boonton, north of Montville, at Jacksonville, Upper Preakness and Caldwell, were all formed by glacial streams while the ice edge was in the immediate neighborhood. The ice seems to have remained upon the higher ground above

and back of these plains, after it had retreated from the lower ground in the same latitude, thus giving rise to the embayment. This is shown (*a*) by the basin-ward slope of the surfaces of the foregoing delta plains, showing that they were built from the highlands; (*b*) by the forward-plunging strata, which, where seen, generally dip towards the lake and away from the highlands; (*c*) by the frequent occurrence at the head of the plains, of bowlder-strewn kames, which mark the position of the ice edge while the plain was forming; and (*d*) sometimes by the forms of the margins of the deltas. Other possible modes of origin were kept in mind as working hypotheses in the field, but were finally abandoned, since they did not harmonize with the facts.

The Upper Preakness stage.—At a number of places more or less well-defined terraces and deltas are present at elevations from 65 to 75 feet lower than the maximum water level. These lower terraces are sometimes directly in front of the higher, which then rise from the upper margin of the lower. In other localities the higher are present without the lower, or the lower without the higher. The two are seen in close connection between Boonton and Montville, at Upper Preakness, and west of Haledon. On the assumption that the tops of these lower terraces represent the approximate level of the water in which they were formed, just as it has been assumed that the surface of the subaqueous overwash plain marks the maximum water level, these terraces mark a subordinate stage in the lake's history. This stage may be called the Upper Preakness stage, from the marked development of the delta plain near Upper Preakness. The field relationships are such as to indicate beyond reasonable doubt that *the lower terraces antedate the upper.* The evidence of the greater age of the lower is not equally conclusive at all points, but nowhere is the relationship between the two such as to necessitate the assumption of the greater age of the upper.

We must conclude, therefore, that the front of the ice became deeply embayed as it retreated from the line of the moraine, and that for a time the waters of the lake sank about 70 feet below

the Madison level. During this stage the lower terraces and deltas observed in the intra-moraine basin were formed, and perhaps also the gravel beds without the moraine near Madisonville, 80 feet below the maximum water level. The Upper Preakness stage was probably a short one, since the terraces are not of great size and deposits of this character were undoubtedly made very rapidly. In order to account for the lowering of the lake level it is necessary to suppose that the lake had at this time a subglacial outlet. This might readily have been brought into existence as the ice retreated towards the Little Falls gap. There are, however, some difficulties involved in this assumption. These will be noticed later.

The Montville stage.—If the higher terraces are younger than the lower, it must be further assumed that the low stage of the lake was followed by a rise of the water approximately to the Madison level. The name Montville is proposed for this stage of the lake. During this stage there were formed the high-level delta plains and terraces north of Parsipanny, near Boonton, north of Montville, at Jacksonville, north of Upper Preakness, west of Haledon and at Caldwell. The ice retreated a little between the Upper Preakness stage and the Montville stage, and the deltas of the latter were built a little back of and above those of the former. In some cases the higher plains reached and partially buried the lower ones. The Montville stage seems to have been a little longer than the Upper Preakness stage. In a few places possible shore-lines have been noted at elevations between those of the Montville stage and those of the Upper Preakness stage, but it has not been possible to correlate them definitely with each other, or to make out their time relationship to other shore-lines. They are best shown on the inner face of the moraine, south of Montville, near Caldwell, and northeast of New Vernon.

If the preceding conclusions as to the relative ages of the Upper Preakness and of the Montville shore-lines be correct, we must conclude that the rise of the water to the Montville level was brought about by the closing of the subglacial outlet. It must be confessed that it is difficult to understand how such an

outlet, once established during the retreat of the ice, could again be closed *during the further retreat of the ice*, when its motion was probably diminishing in vigor, and when its rate of melting was very likely increasing, and when it was becoming thinner. Nevertheless, the stopping of the outlet, even under these adverse conditions, seems to be indicated.

The final draining of Lake Passaic.—After the Montville stage had endured for a time sufficient for the formation of the glacial deltas which mark that stage, the ice was melted back so as to permit the escape of the lake drainage through the Little Falls and Paterson gaps. The intra-morainic part of the lake was soon drained to the level of the barrier at Little Falls, 175 to 190 feet. Below this level in the area of the Great Piece and Troy meadows, and perhaps in Black meadows and Hatfield swamp, shallow bodies of water may have lingered until the outlet was brought down to this level. Such bodies of water must have existed for a time, if relative levels were the same as now. As deformation of the basin has taken place since the ice disappeared, it may be that these swampy areas were not then lower than the Little Falls outlet. After the Little Falls outlet was established, a small post-glacial lake remained in the extra-morainic basin over the low land between Second mountain and Long Hill, in the valleys of the Passaic and Dead rivers. It was held at 230 feet by the drift barrier at Stanley, through which the river has since cut a passage.

Judging by the meager developments of the shore features of Lake Passaic save in those cases where the supply of material from the glacier was abundant, their indefinite form in many instances, and their entire absence in localities where they might rationally be expected to exist, we cannot but conclude that the entire life of the lake, was, geologically speaking, brief. During its maximum extension, just before its final draining, Lake Passaic must have been about 30 miles long and 10 miles wide at its widest part. It must have had a maximum depth of about 225 feet in the intra-morainic part, and of about 140 feet in the extra-morainic.

The sequence of events outlined above is based upon the assumption that all the drift in the Short Hills gap is late glacial, and that, until the ice reached the line of the moraine, drainage escaped through this gap at the level of the rock bottom. The presence of the thick deposits of (lacustrine ?) clay in the region of the Great Swamp, which by their relationship to overlying deposits, are clearly shown to antedate the moraine and accompanying overwash plain, indicate that a lake may have existed in the Great Swamp area for a considerable period before the ice of the last epoch formed the moraine.

Three hypotheses concerning a pre-morainic lake in the Lake Passaic region may be considered. (1) Some part, perhaps a large part of the drift filling of the Short Hills gap, may belong to an earlier ice sheet which deposited the extra-morainic drift found more or less abundantly about the lake basin and above the lake level. In this case, the inter-glacial drainage may have been through the Little Falls outlet and Lake Passaic may have come into existence, so soon as the ice of the last epoch closed the Little Falls gap. Under this hypothesis, the Great Swamp clays would be referred to this early stage of the lake's history. In this event we must suppose that the ice advanced very slowly, so slowly that a great thickness of clay accumulated before the deposition of the overlying loam, sand, and gravel, which are contemporaneous with the moraine or which but slightly antedate it. The clays north of the moraine, which are similar to lacustrine clays, are also in general at low levels, and so far as elevation goes, may have been formed in such a lake.

(2) We may conceive that the earlier ice invasion wrought such changes in the preglacial topography, that, after its retreat, a low-level lake occupied the area of the Great Swamp, and perhaps also the lowlands northeast of the moraine. In this inter-glacial lake much of the lacustrine clay may have been formed. We may suppose further that the lake was drained during inter-glacial time by the clearing out of the Short Hills gap. In this case we should expect to find the clays overlain by an old soil developed after the lake was drained. Above this old

soil would come whatever deposits were made in the lake basin during the later glacial invasion. So far as known, such an old soil does not exist, but observations are not numerous enough to prove its absence.

(3) The third hypothesis differs from the second only in the assumption that the inter-glacial lake lasted until the later ice invasion, and was continuous in time with the lake formed in consequence of that ice invasion.

The first hypothesis makes the clays, so far as they are lacustrine, entirely late-glacial. The great objection to it is the very long time required for the advance of the ice, in order to permit the formation of so great a body of clay, compared to the brief time of its maximum extension and retreat. The retreat must have been rapid, since the silts and sands correlated in time of origin with the moraine, are not buried by later deposits. The second hypothesis makes most of the clays early glacial and inter-glacial, and seems to demand an old soil separating these deposits from later ones. Such a soil is not known to exist. The third hypothesis makes most of the clays early glacial and inter-glacial, and it demands their transition upward into the later deposits without a break. Sufficient data are not available to permit a decision in favor of any one of these hypotheses.

DEFORMATION OF THE LAKE BASIN.

The highest shore-lines of Lake Passaic are no longer at a constant elevation with reference to the present sea level. At the southern end of the lake, the highest shore-line has an elevation of 345 feet;[1] at the Moggy Hollow outlet, about 356 feet; at Morristown about 376 feet; at Boonton about 394 feet; at Montville about 398 feet; at Jacksonville, 408-9 feet; north of Upper Preakness, about 412 feet. On the eastern side of the lake the shore-line increases in elevation from south to north. At Mt. Bethel it has an elevation of 350 feet; at West Summit

[1] Elevations in most cases were determined accurately by two men working with a rod and level, from bench marks established during the topographical survey of the state.

probably 367 feet; at Caldwell, 385 to 390 feet; at Haledon it is 405 feet.

These figures show that the shore-line rises from 345 feet to 412 feet from the southern to the northern end of the lake. The shore-lines, however, do not rise most rapidly in the direction of the longer axis of the lake, from southwest to northeast, but rather from south to north. Calculated in this direction, the rise is 67 feet in 25 miles, giving a gradient of two and two-thirds feet per mile. This rise northward is by no means regular. Within short distances, the gradient varies from nearly four feet per mile to less than one foot. In one or two instances, notably along the subaqueous overwash plain, the shore-line, after making all possible allowances, seems to be slightly lower than at points further south and southwest. The differential northward elevation of the lake basin, following the withdrawal of the ice, did not proceed with a constant gradient. It was rather of the nature of an irregular warping and incipient buckling, with the greatest rise to the northward.

The deformation of the shore-lines occurred after the lake was drained, rather than during different stages of the lake. This is shown by the fact that the Upper Preakness shore-line is everywhere about 70 feet below the Montville level, whereas, if any deformation had occurred in the interval between these two stages, their shore-lines would not be essentially parallel.

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DESCRIPTION OF A NEW SPECIES OF *PETALODUS* (*P. SECURIGER*) FROM THE CARBONIFEROUS OF ILLINOIS.

THE species here described resembles most closely the form described by Messrs. Newberry and Worthen as *Petalodus destructor* (Geolog. Survey of Illinois, 1866, Vol. II., p. 35, Pl. II., Figures 1–3).

The size is large, the extreme length being 56^{mm} and the greatest width of the crown 47^{mm}. It is therefore somewhat larger than the teeth figured by the authors named above; but the difference is not great, and the teeth of the two species may be properly compared.

The width of the crown of *P. securiger* is greater than that of *P. destructor*. The height of the crown of the former, measured from the apex to the lower border of the enamel band on the posterior surface, is exactly that of the tooth figured by Messrs. Newberry and Worthen. Nevertheless, the width of the crown of the latter specimen must be increased by an eighth of itself in order to equal the width of *P. securiger*. The crown of the latter is also less acuminate than that of *P. destructor*. The lateral angles of the two teeth are different. Those of *P. destructor* terminate acutely, while those of *P. securiger* are rounded off. That this condition is not due to wear is shown by the fact that the enamel folds, as they approach the border of the tooth, become directed upward.

The width of the band of enamel folds is also greater in the tooth being described than in *P. destructor*. In the latter, as we find it figured, the width of the band in the middle line of the posterior surface is contained in the distance from the band to the apex of the tooth four times. In *P. securiger* the width of the band is contained in the distance named only three times. In *P. destructor* the band is described as consisting of five or six

folds of enamel; in *P. securiger* there are eight or nine distinct folds.

In another important respect *P. securiger* appears to differ from *P. destructor* and all other described species of the genus. The uppermost border of the enamel band stands out boldly from the general surface of the crown on both the anterior and posterior sides of the tooth. On the posterior side there is thus a distinct valley formed above the enamel band. In the section of the tooth figured by Messrs. Newberry and Worthen the lower

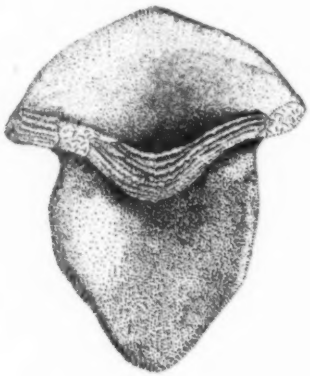

FIG. 1.

border of the enamel band is represented as standing out from the general surface of the tooth on the posterior side of the latter, but nowhere else. The arrangement of the enamel band of the tooth in hand suggests that the cutting edge of the tooth standing in the opposite jaw, and against which our tooth bit, fitted, in the closed mouth, into the valley formed by the band of enamel.

The root of the tooth of *P. securiger* is considerably broader than is that of *P. destructor*. The posterior surface of the root is concave in transverse section at the middle of its length, while it is convex in longitudinal section.

On its posterior face the enamel, for a short distance below

the cutting edge, shows a worn surface, where it has come into contact with other teeth.

Dr. Joseph Leidy (Extinct Vertebrate Fauna, p. 312, Pl. XVII., Fig. 3) refers *P. destructor* to his own earlier described *P. alleghaniensis*, and Orestes St. John agrees with the conclusion.

In case this identity is established the availability of two other specific names will have to receive consideration. One of them is *extinctus*. This was proposed by Dr. Leidy in 1855 (Proc. Acad. Nat. Sci. Phila. Vol. VII., p. 414), but later the author essayed to withdraw it in favor of *alleghaniensis*. But there is a still older name which may supersede one or both of the names *alleghaniensis* and *destructor*. In the Amer. Jour. of

FIG. 2.

Science, 1853, Series 2, Vol. XVI., p. 142, Professor J. M. Safford described and gave two wood cuts of a species of *Petalodus*. On this was bestowed the name *Getalodus ohioensis*, but the error in the generic title is evident. This name and the figure appear to have dropped out of sight. Although Professor Safford's specimen lacked the root, the crown was complete and closely resembles that of *Petalodus destructor*. The angles of the tooth are, however, rounded off like those of Dr. Leidy's figure of *P. alleghaniensis*. The size, if we may depend on Professor Safford's drawing, is more nearly that of *P. destructor*. It is not improbable that Professor Safford's drawings are not wholly accurate and this fact may account for the distance of the enamel band from the apex on what is evidently intended for the anterior face of the tooth. It would be interesting to know whether or not the type of Professor Safford's specimen is yet in existence. In any case, the name must be recognized as that of one of our species of *Petalodus*. Should it also result, as is not impossible, that the

species *P. alleghaniensis, destructor* and *securiger* shall prove to be one, then it appears reasonable that they shall receive the name *P. ohioensis*. As regards the relationship of *P. alleghaniensis* to *P. destructor* it must be noted that the teeth called by the former name are considerably smaller, the breadth of the crown of the one figured in the "Extinct Vertebrate Fauna" having a breadth of crown of only 20^{mm}, while the crown of the specimen figured by Messrs. Newberry and Worthen has a width of 42^{mm}. For the present I am inclined to regard *P. alleghaniensis* and *P. securiger* as distinct species and to refer *P. destructor* to *P. ohioensis*.

Figure 1 represents the posterior face of the tooth of *P. securiger*, while Fig. 2 is intended to present a section through the tooth. However, the anterior face of the root has not yet been freed from the matrix. Two teeth of this form have been brought to me by Mr. Harry Derr, of Chicago, who collected them in the Carboniferous limestone at La Salle, Ill. One of the teeth was considerably broken and parts were missing.

To Professor C. W. Rolfe, of the University of Illinois, I am indebted for information regarding *P. destructor*.

O. P. Hay, Ph.D.

Field Columbian Museum,
Chicago, July 12, 1895.

GLACIAL STUDIES IN GREENLAND. VI.

THE REDCLIFF PENINSULA.—*Continued.*

The Bryant glacier.—In a valley about three miles east of the Fan glacier there lies another tongue of the peninsular ice-cap to which the name Bryant glacier has been applied. Like the Fan glacier it is but a short lobe protruding from the ice mantle of Redcliff peninsula on its southerly side. It descends an open valley less than a mile in width, and by estimate less than three miles long. Its course is direct and its slope somewhat greater than that of the Fan glacier, as will be seen from the photographic illustrations, Figs. 31 and 32.

The most striking characteristic of this glacier is the verticality of its face. In this particular it introduces us to the prevailing northern type. Attention has heretofore been called to the curved profile of the terminal slope of the glaciers of Disco Island, and of southern latitudes generally. The Igloodahomyne glacier which we first visited in the northern latitudes does not very widely depart from these. The Fan glacier approaches verticality in its lower face, but its brow is so much curved and the cones and snow embankments along its face covered so much of the vertical part of its front that it falls short of a typical expression of the northern habit. In the Bryant glacier, however, verticality of face reaches a full and characteristic expression. Not only is the face vertical but it is disposed to overhang so that from time to time the upper portion breaks away and falls to the base. This disposition to overhang is doubtless to be attributed partly to the more rapid movement of the upper layers of ice and partly to the more rapid melting of the discolored ice below, the two agencies acting jointly. The verticality is not only a characteristic of the end of the glacier but of the sides. This seems less strange, however, for here we might find a plausible explanation in the undermining of the streams

that run alongside the glacier and constitute its main drainage system, and in the reflection and radiation of heat from the adjoining cliffs. But neither of these afford an explanation of the abruptness of the end of the glacier. This terminates upon a flat gravel plain produced by the glacial wash, and no cliff lies in front between it and the Gulf, a mile or two distant. As this glacier has a southern frontage, the phenomenon might perhaps at first thought appear to be due to exceptional exposure to the southerly sun, but the sun is less partial in its favors here than in southern latitudes. During the main melting season it is constantly circling above the horizon and throwing its rays on all sides of the glacier, and, although the southerly sun is more effective than any other, the difference is less than in lower latitudes. Besides, we shall find in the study of other glaciers of the region that eastern and western and even northern exposures present the same characteristics. The explanation seems to lie in the low inclination of the sun's rays and in their impact from all points of the compass in succession. It is obvious that rays of low slant strike the back of the glacier at a very acute angle and easily glance away with little effect. On the edge of the glacier, however, they strike more directly against the surface and hence have greater effect. In addition to this, the slanting rays that impinge on the surrounding surface at low angles are again reflected at like low angles, and hence a much larger proportion of them strike upon the edge of the ice. Thus it appears that a larger *proportion* of the sun's rays fall on the edges of a glacier in high latitudes than upon the edges of a glacier in low latitudes, and it is obvious that it is the *proportional* effect of the sun's rays that determines the contour. For like reasons there is a larger proportional reflection from prominences in the vicinity of the ice, so that, although verticality of face is not dependent on the presence of reflecting cliffs near the glaciers, it is facilitated by them. It will be found in subsequent observations that where promontories of rock rise through the ice-sheet, forming the "nunataks" of the Greenlanders, the ice, in many instances, does not crowd against their sides but is

FIG. 31.—Terminal portion of Bryant glacier seen from the east, showing clean, white ice above and stratified, discolored ice below, with a talus slope at the base. Height of vertical face above the gravel plain in front about 140 feet. In this and the following views the amount of débris in the discolored ice is greatly exaggerated by surface spreading.

FIG. 32.—Middle portion of Bryant glacier seen from the east, showing increased thickness of white ice above and the curvature of the discolored layers below.

melted back, leaving a moat-like ditch between the eminence and the mass of the glacier surrounding it, not unlike the defensive trench of an ancient castle. Whenever the motion of the ice is considerable, however, this intervening space is absent and the ice impinges forcibly upon the base of the prominence.

So striking a feature could not well escape the notice of previous visitors to the region. In the Greeley reports the designation "Chinese Wall" is aptly applied to it. Its significance and especially the internal structure and mode of action which it reveals were not unnaturally overlooked amid the engrossing demands of other interests.

Stratification.—This melting back of the edge of the ice, developing a vertical face in the place of the usual slope, is a matter of the utmost good fortune to the glacial student, as it displays the basal organization of the ice and reveals its methods of work to a degree that could scarcely have been anticipated. It is as though a Titan with the blade of a giant knife, one or two hundred feet long, had sliced away the border of the glacier, giving us a vertical section across the end and along both sides. This truncation of the edge reveals a remarkable stratification of the ice and an equally remarkable insetting of rock débris. The stratification of glaciers is by no means an unknown phenomenon, but I doubt whether it had ever been suspected that it reaches an extent and an intimacy such as is here displayed. As will be readily seen from the accompanying photographic illustrations, the ice is not only arranged in layers, but these are subdivided in a very intimate fashion, so intimate indeed in many portions as to pass beyond simple stratification in its usual sense and become lamination. In extreme instances the thin layers number as many as twenty to the inch. By turning to the illustrations (Figs. 31, 33 and 35, in particular) it will be seen that there is a thick stratum of clean, white ice at the top, beneath which there is a zone of ice darkened with much débris, and at the bottom a talus slope formed from a mixture of ice and rock fallen from above, commingled with the residue of snow drifts. The talus slope rises to heights of thirty and forty feet, and occasionally more.

FIG. 33.—Terminal portion of Bryant glacier seen from the west, showing the stratification and lamination of the ice and the talus slope below. Inglefield gulf seen in the distance at the right.

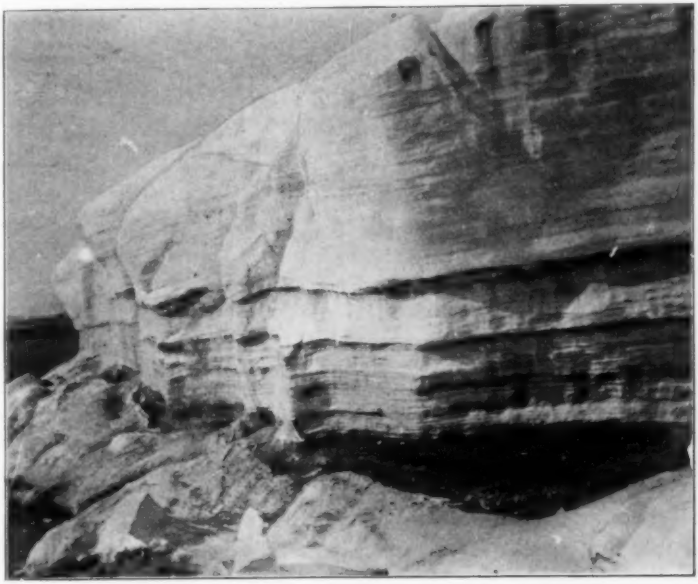

FIG. 34.—Portion of the "Chinese Wall" showing distinctly the stratification of the white ice as well as the discolored portion. It illustrates also the arrangement of the rock débris in definite planes.

The discolored ice above this measures fifty or sixty or even seventy feet, while the white ice above is forty or fifty feet thick at the edge, and rapidly increases backwards. Measurements made with a binocular Locke level by sighting across the extreme front of the glacier from the adjacent slope showed that the discolored ice rose ninety-five feet above the gravel plain in

FIG. 35.—A nearer view of a portion of the front of the Bryant glacier near the middle of the valley, showing the verticality of the face, the stratification of the ice, the insetting of the bowlders, the formation of the talus, and the smoothness of the valley bottom.

front, while the white ice rose forty-five feet above this, making the total vertical height of the extreme front 140 feet.

The stratification is not confined to the discolored portion, although it is only obscurely expressed in the white ice. Nor is the stratification of the two parts identical. Perhaps it may be appropriately said that there are two classes of stratifi-

cation. The one predominates in the white ice and the other in the discolored. The first consists of an alternation of layers of porous, opaque, white ice with layers of compact, transparent, blue ice. The blue layers are thin, while the

FIG. 36.—Nearer view of the middle of the front wall of the Bryant glacier, showing details of stratification and the trench cut in the face of the glacier and of the talus slope by a small stream descending from the surface of the glacier.

white layers are relatively thick. This form of stratification extends into the discolored portion, but the distinctive stratification of this portion consists of the introduction of layers of rock débris between sheets of ice. In general this débris was found

to be confined to very definite planes. In some places there was a somewhat promiscuous scattering of the rock material through the ice, and in exceptional cases considerable thicknesses of ice were freely inset with foreign matter, but as a rule the erratic material was distributed in extremely thin sheets between layers of ice that remained essentially pure. The typical section was therefore made up of layers of pure, clean ice separated by films of rocky débris. The rocky material varied in size from the finest silt up through pebbles and fragments of various sizes to bowlders or blocks of rock several feet in diameter. There was no special assortment of this material. Between the same two layers of ice might be found, here an attenuated film of fine silt,

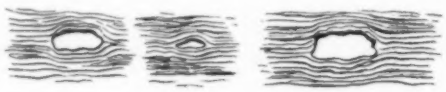

FIG. 37.—Diagrams illustrating the behavior of the laminæ of the ice in passing embedded bowlders.

a little farther on a layer of sand, or a pebble, or a chip of rock, or all these together, while now and then a bowlder or massive block might be encountered. It was observed that usually these larger pieces centered upon the plane of débris, a portion of their mass rising above it and a portion sinking below it. Where the ice was closely laminated the larger fragments necessarily extended across the horizon of several laminæ, and it was interesting to observe that in many of these cases the laminæ divided, a part bending up and passing over the rock fragment and a part bending down and passing under. In cases where the mass was large, some of the central laminations ended abruptly against the mass and new laminations appeared on the opposite side, while the laminæ above and below were bent around the mass as illustrated in Fig. 37. I observed no cases in which the mass seemed to have descended through the ice, as though carried down by its superior gravity. In such a case it would be presumed to bend the laminæ down with it, or break across them. It appeared,

on the contrary, that the larger masses of rock equally with the smaller remained fixed.

The material embraced in the ice was found to consist in large part of indurated quartzose sandstone of a light pinkish-gray color. This appeared to be the sandstone previously described as constituting the second member of the clastic series. It comes out to the surface on the eastern side of the peninsula, forming the very picturesque cliffs of Karnah, and may be conveniently known as the Karnah sandstone. Besides this, there was some reddish sandstone and shaly débris belonging to the other members of the clastic series. There was also present a notable ingredient of crystalline rock, chiefly of the gneissic and granitic types. This constituted a decidedly subordinate percentage of the whole, but it was rendered conspicuous by its nature and is significant in that it indicates the existence of the gneissic series underneath the ice-cap somewhere between this glacier and the center of the peninsula, and it will be recalled that the peninsula is only about fifteen miles across.

By reference to the illustrations it will be seen that the number of layers of débris in the lower part of the Bryant glacier is very large. It is important to observe, however, that the amount of débris appears very much greater than it actually is because of the spreading of the silt over the face of the ice when it was freed by melting. Fig. 38 shows a portion whose layers were upturned at the foot of the glacier. The surface wash was cut away from a belt across the layers and a comparison of this with the rest will show the deceptiveness of the dirty surface. In a similar way natural surfaces that have been washed by streamlets from the surface of the glacier show the true content of débris.

The laminations that bear the débris are not usually continuous for very great distances. The first impression, perhaps, made on viewing the wall of discolored ice is that the more pronounced layers are continuous across its whole breadth, but upon closer inspection it will be seen that the layers thin out and disappear and others are introduced to take their places; even the broader bands are limited in their extent. None of them save,

perhaps, the twofold division, appear to pass from side to side of the glacier. This may be verified by comparing the east, the frontal and the west sides as shown in Figs. 31, 35 and 33.

The laminæ are generally plane or slightly undulatory and essentially horizontal, but occasionally they are warped and crumpled; sometimes they are faulted.

The major planes of stratification seem to be essentially parallel with the bottom of the glacier. In detail this is not always true, and theoretically it is probably not accurately true as a generalization — but in a broad sense it appears that the attitude of the layers is controlled by the bottom and not by the top of the glacier. The profile views illustrate this. Apparently the white ice thickens rapidly as we go back from the edge, while the discolored ice at the base probably remains approximately constant in thickness. This seems to me to agree with theoretical presumptions. The melting of the glacier is chiefly at the surface. There is little ground for believing that any considerable amount of interior melting takes place that is not compensated by refreezing. Hence the upper layer must thin out as it approaches the edge of the glacier, while the lower layers remain approximately constant. The ratio, therefore, of the débris-bearing ice to the white ice above it, as seen on the edge, cannot be regarded as applicable to the thicker portions of the glacier back from the edge. At the extreme margin of the Bryant glacier the débris-bearing ice constitutes two-thirds of the section. It certainly would lead us far astray to assume that the débris is distributed through two-thirds of the vertical section of the ice on the summit of Redcliff peninsula.

The drainage of Bryant glacier is essentially the same as that of the two northern glaciers previously described. The waters produced by melting are shed from the back of the glacier in rivulets, very few of which find an opportunity to descend to the bottom through crevasses because of the scantiness of these. The rivulets, however, instead of cascading down the sloping face of the glacier as they were permitted to do in the preceding instances, are forced to project themselves from the overhanging edge as

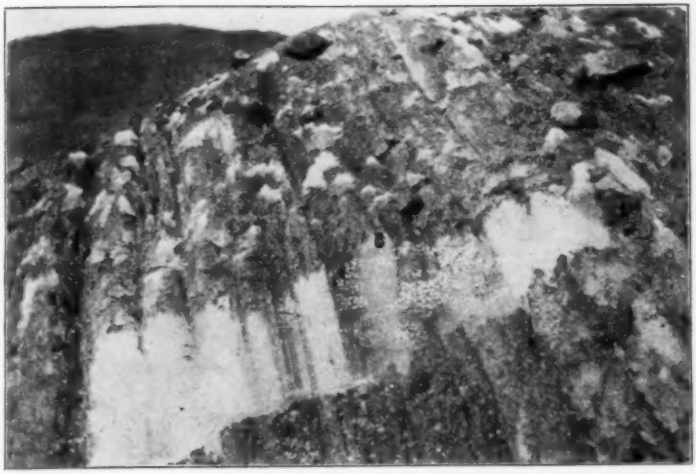

FIG. 38.—A nearer view of the débris-bearing layers which have been curved upwards to a nearly vertical position. From a portion of this the discolored surface has been cut away to show the difference between the real amount of débris included in the ice and the apparent amount deceptively indicated by the surface spreading. It also shows the definite arrangement of the internal débris in layers.

FIG. 39.—A portion of the front of Bryant glacier near the west side of the valley showing the inconstancy of the laminations and the formation of a monument of discolored ice off the face of the wall by the melting or falling away of the ice that once surrounded it.

free-falling little cataracts. Along the sides of the glacier these are gathered into a considerable lateral stream which occupies the trench between the glacier and the side of the valley. At the end of the glacier small streamlets flow away in large numbers but there is no central stream, nor any large central tunnel after the fashion of Alpine glaciers. The lateral streams are usually murky, but the frontal streams are essentially clear.

The plain in front of the glacier is produced by its own drainage and consists of bowlders, cobbles and coarse gravel, with some sand and silt. It spreads from bluff to bluff in a nearly uniform plane. There is no terminal moraine immediately in front of the glacier, unless the talus at its base be so regarded. Between its extremity and the sea, along the sides of the valley, there are some accumulations of erratic material that perhaps represent old moraines, but they scarcely have a distinctive character.

Ascent to the ice-cap.—On two occasions we ascended the plateau immediately east of Bryant glacier and went back to the edge of the ice-cap of the peninsula. At first the surface was found to be formed wholly of frost-riven fragments of the sandstone and shale series that constitute the uppermost member of the clastic terrane before described. Here and there an erratic bowlder was seen, but the amount of detectable drift on the surface was very small. At a height of about 1600 feet and at a point perhaps two miles back from the Gulf, moraine-like aggregations of rounded erratics were met. These did not form a sharply defined moraine with a definite outer border, but the transition from local débris was measurably abrupt. As the ascent was continued there was an increase in the amount of drift and the topography became more moraine-like, although it never passed beyond the milder type of morainic hills and hollows. The material was chiefly bowlders ranging from one to three or four feet in diameter. Cobbles and coarse gravel were present, but sandy and clayey constituents were scant. As the edge of the ice-cap was approached streamlets issuing from the border of the ice were encountered and became increasingly frequent. They

had brought down with them gravel and sand and by spreading these out had smoothed the surface in a notable degree. Streamlets were abundant on the plateau surface even within short distances of the edge of the valley occupied by the Bryant glacier and seemed to quite ignore its existence. This seems to mean the same thing as the absence of a central stream under the

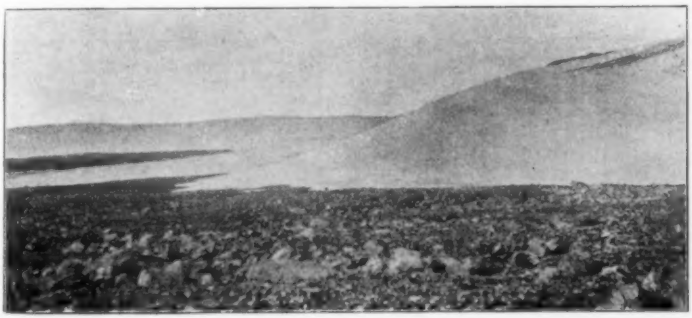

FIG. 40.—The southern edge of the ice-cap of the Redcliff peninsula a short distance east of the Bryant glacier (which is represented by the lowest white band that reaches the left border of the picture, the valley occupied by it being sunken below the level of the plateau so as to nearly conceal the glacier). The foreground is the gravel plain formed by streamlets issuing from the ice-cap. The snowy slope at the right is the wind-drift border lodged on the edge of the ice-cap. The terminal moraine is barely seen at the top of this, together with a belt of surface wash from a portion of the moraine not seen. In the background at the left is a more distant portion of the ice-cap. View taken looking westward.

valley glacier, viz., that there is little or no gathering together of water beneath the glacier.

The base of the ice-cap was reached at a height of about 2000 feet. It lay perhaps three miles back from the border of the gulf. No measurements of distance were made and this and similar statements in this article are only such rude approximations to the truth as may give a general impression of distances. It was not thought wise to consume precious time in measurements where accuracy had no importance.

The edge of the ice-cap was found to consist of a steep snowy slope rising to a height of about 100 feet, crowned by a terminal

moraine, beyond which rose the great dome of the ice-cap. Strangely enough here was a terminal moraine that was not terminal; a terminal moraine with an icy tract outside. This outer tract was in part fresh snow almost perfectly white, indicating that it was a wind-drift accumulation of recent date. At points, however, older discolored snow or ice appeared beneath it and in a few places stratified granular ice of glacial aspect and con-

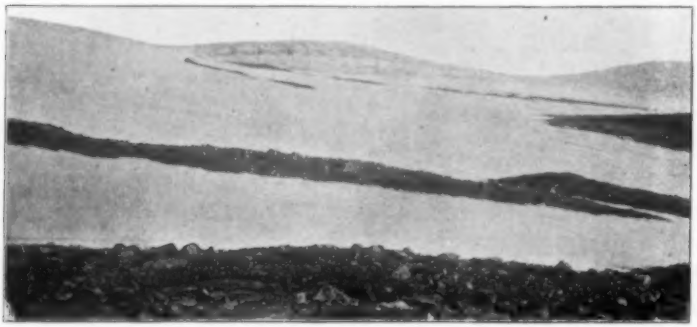

FIG. 41.—Southern edge of the ice-cap of Redcliff peninsula seen looking eastward from a point a short distance east of the Bryant glacier. The débris-strewn portion of the plateau forms the immediate foreground. Beyond this is the wind-drift belt of snow lodged outside the terminal moraine which lies just beyond it in the middle foreground. The dark lines of débris in the center of the picture are also parts of the terminal moraine which pursues a serpentine course controlled by the topography. The white portion in the center and at the left and the dome in the background are parts of the ice-cap.

taining some rocky material was seen. It was not clear, however, that this was not material that had rolled down the steep slope from the moraine above. The phenomenon was at first exceedingly puzzling, but subsequent study and the light which Lieutenant Peary threw upon the subject rendered the elucidation altogether clear. Lieutenant Peary (who had not yet been met) subsequently informed me that the winds of the ice-cap usually flow down its slope much as though they were independent and simply controlled by gravity. It is easy to see that the air in contact with the surface of the ice-cap becomes exceptionally cold.

The high specific gravity thus acquired is apparently sufficient to give it motion down the slope measurably independent of the general movement of the atmosphere, unless the latter is strong, hence the predominance of winds flowing down the slope of the ice-cap in lines normal to its border. By these snow is carried in large quantities over the moraine at the edge of the glacier and is lodged behind it. Thus arises an exceptional snow accumulation on the outer border of the moraine. This is so great in amount as to resist the limited melting of the summer and hence it persists from year to year and becomes solidified to a glacier-like consistency; indeed it may be regarded as a species of fringing glacier. Lieutenant Peary says that it is a prevalent phenomenon, not only around the borders of Inglefield Gulf but on the northeastern side of Greenland so far as reached by him in 1892. This wind-drift border varies in extent from a few rods to half a mile in breadth at the points where I saw it. Where first encountered on the plateau east of the Bryant glacier, it only reached a short distance in front of the terminal moraine. (Fig. 40.) A little to the east it was found to be considerably wider and in an adjacent depression to extend itself as a tongue a mile or so down the valley. Fig. 41 shows a portion of this wind-drift border of relatively flat surface and narrow breadth, as seen a short distance east of the Bryant glacier.

The acclivity of this border where I first encountered (Fig. 40) it was so steep as to make direct ascent difficult, but oblique ascent was found practicable, with a little care. On reaching its summit a sharply ridged moraine was found, the outer face of which was as steep as the material would lie. Indeed, some of the material appeared to have been dislodged and to have rolled down the snowy declivity. Just there the moraine only rose ten or twelve feet above its outer base, though elsewhere it appeared to reach a height of twenty or thirty feet. Beyond the sharp crest there was a descent of a few feet, and then an irregular surface a few rods in breadth. Inside this narrow and apparently shallow moraine and parallel to it, there ran a little brook fed by numerous streamlets from the ice-cap beyond. This brook ran along

between the moraine and the ice-cap for some distance to the eastward until it found a low point in the moraine, across which it flowed and became lost in the snowy slope fronting the moraine. It doubtless represents a mode of drainage of some prevalence during the glacial period. Beyond this infra-morainic brook the ice rose with a moderate slope up to the summit plane of the ice-cap.

On neither of my two visits to the ice-cap at this point did

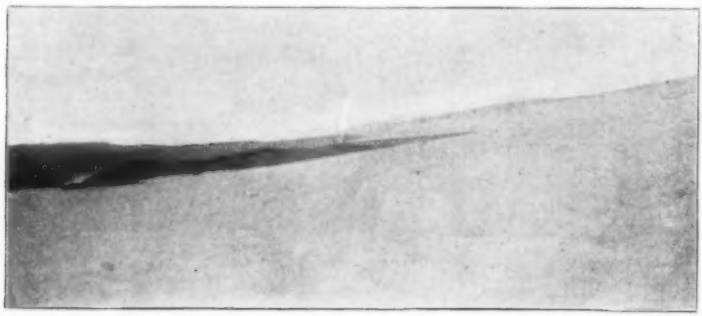

FIG. 42.—A portion of the Redcliff ice-cap seen from a point on the ice-cap looking westwardly, showing the terminal moraine at the left with a glimpse of the snow border beyond and the smooth summit lines of the plateau in the distance.

time permit any considerable ascent of its border. It was estimated to rise one or two thousand feet, and this accords with the estimate of Lieutenant Peary formed on better grounds. The surface of the ice-cap, except in the immediate vicinity of the frontal moraine, was found to be entirely free from débris, except atmospheric dust lodged upon it. No bowlders whatever were seen upon it. Crevasses were absent from the border of the ice-cap, so far as it was traversed, with the exception of mere cracks which did not appear to descend deeply, as they did not absorb the streamlets running over the surface. Dust wells and dirt holes were abundant, usually reaching six or eight inches in depth.

It will be observed that the terminal moraine lay between the wind-drift border and the ice-cap. We were very much struck

at first sight with the angularity of the contours of the moraine. It presented the appearance of having been pushed up from beneath. At some points there were sharp conical peaks that gave the impression of direct elevation from below. This appearance was afterwards supported by observations elsewhere and there seemed sufficient grounds for believing that the impression of the method of its formation was correct. It was found that the layers of the ice curved rapidly upward on encountering the wind-drift border and the moraine lodged against it, and that the morainic débris that resulted from its melting was borne on its upturned edge. Under these conditions any motion of the layers of the ice must have pushed upwards the material lodged upon their edges.

The material of the moraine was in general quite angular. There were occasional well rounded cobblestones and some well worn bowlders, while some other fragments were deangulated or rubbed and bruised, in a moderate measure, but notwithstanding these instances, the prevailing character was one of marked angularity. The material was chiefly light colored sandstone of the Karnah variety previously alluded to. Some crystalline bowlders were present. It would appear, therefore, either that the ice-cap was largely underlaid with Karnah sandstone, or else that the débris was chiefly picked up near its border, and of these alternatives the latter seemed best supported by the distribution of the formations and other considerations.

This moraine was seen to reach along the edge of the ice for some miles. To the east it could be seen pursuing a serpentine course along the ice front with a notable snow-drift belt outside. To the west it could be followed for a shorter distance beyond which its presence could not be detected, the ice-cap appearing to come down with a moderate slope to the surface of the plateau without any frontal moraine. But this tract was only seen from a distance and a moraine buried beneath a snow-drift border may have been present.

The ice front showed little evidence of motion. It appeared from the constitution of the wind-drift border that it was the

result of several years' accumulations, but it did not appear to be disrupted or disturbed in any observable degree by pressure from the ice-cap beyond. The moraine, pushed up between the ice-cap and the snow-drift border, showed evidences of motion, as already indicated; but this must have been very slow, otherwise the moraine would have been pushed over the wind-drift border or both pressed forward together, of which there seemed to be no evidence. The material rolled along by the little fringing streams that bordered the ice-cap, was found to be rounded up to the very edge of the snow-drift border, and this strengthened the conviction that these little streams had been engaged in their work for some considerable period. Individually they were usually mere little shallow brooklets and the amount of erosion they could accomplish in a single year would be slight. The impression of slow motion and limited vigor was further strengthened by the fact that the water of these little streamlets was clear and free from observable silt. Had the ice been moving at any notable rate, or acting with any appreciable vigor on the angular sandstone at its edge and in its bottom, the issuing streams could scarcely have failed to be silty.

T. C. CHAMBERLIN.

EDITORIAL.

WHILE polar exploration is less in the minds of the public than it was last year, it is quite probable that the results of the current season will prove more ample. Reports from the north indicate more favorable conditions and there is ground to hope that the exceptional severity of the weather which so seriously interfered with the work last year will be offset by an exceptionally open season. Peary, Jackson and Nansen may all possibly return laden with rich results, though the last cannot certainly be expected, even though he should be ultimately successful. Lieutenant Peary is quite certain to return and there is good reason to believe that the success of his earlier attempts will attend him this season. The expedition which goes to the north to bring him back is under the immediate direction of his brother-in-law, Mr. Emil Diebitsch, a civil engineer, who was a member of the expedition last year. Professor R. D. Salisbury goes as the geologist of the expedition, and, unless circumstances are peculiarly adverse, he may be trusted to bring back much valuable data. His field will be much the same as that of the writer during last season, but it is expected that a larger portion of his time will be devoted to southern Greenland, the purpose being to develop more fully the differences in the effects of latitude which were found to be very notable last year. The expedition is expected to return about the first of October.

Much interest is being awakened in the exploration of the Antarctic regions, and the subject received earnest consideration at the recent International Geographical Congress in London; indeed the discussion of this subject appears to have been the notable feature of the congress. Although the meager reports of the press do not indicate the precise plans recommended, it

may safely be assumed that out of the conjoined wisdom of so many experienced explorers the best ideas in polar exploration will find expression in the expedition or expeditions that it is hoped will spring out of the agitation. Dr. Cooke is laboring industriously in the endeavor to organize his proposed Antarctic expedition, but with what success we are not informed. Obviously he is hampered somewhat by the moral effects of the ill success of the Miranda expedition of last season. Altogether there is much ground of hope for important returns at the close of the season and for new enterprises in the early future.

T. C. C.

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The size of this number has been reduced and its issuance delayed by an oversight and by the failure to receive in time the proof of an article whose author is doubtless in the field. As the last numbers have considerably exceeded the standard size and succeeding numbers are likely to do so also, our readers will doubtless generously overlook the shortage of this number.

T. C. C.

PUBLICATIONS.

Elements of Mineralogy, Crystallography and Blowpipe Analysis, from a Practical Standpoint. By ALFRED J. MOSES and CHARLES L. PARSONS. 342 pp., 336 cuts, 1895.

The object of this book as stated in the preface is to present in a clear, concise and scientific manner, the nature and uses of minerals and the method for ready and rapid identification.

The regular arrangement of the mineral characters renders it a valuable reference book for one who has but a slight knowledge of the subject, enabling one to turn quickly to the portion he may at any time wish to know, whether this be the physical or chemical properties or blowpipe tests or uses. This is one of the very commendable features of the book, for it is often convenient to turn to these important characters quickly without looking through many pages of detailed description. The book is divided into four parts of which the first treats of the laws, nomenclature and systems of crystallography, and is illustrated by numerous figures. The use of the term *group* as synonymous with *system* is perhaps to be questioned, for while the crystallographic system comprises all forms referable to the same axes, the term group comprises all systems whose forms possess the same number of principal planes of symmetry.

Part II. is a concise treatment of the methods of blowpipe analysis. The chapters on useful tests with the blowpipe, alphabetically arranged, and on qualitative schemes for such analysis will be of special interest to students of mineralogy as affording a quick method of determination.

Part III. is devoted to descriptive mineralogy. While one of the very distinctive and admirable qualities of this book as a practical guide is its conciseness of statement, this feature in the opening chapter of the third part has been carried too far for clearness. The definition of phosphorescence is too comprehensive and for fluorescence is too limited. A student would be apt to confuse the ideas of cleavage and gliding on account of the very brief statement of gliding placed in the section on cleavage. The main portion of this part and over

one-half of the book is devoted to descriptions of the various minerals. The economic importance of the minerals is clearly pointed out, then the composition and general description is given, followed by the physical characters, action before the blowpipe, and similar species noted. A list of important localities is also added. The important minerals are printed in ordinary type, while less important ones are printed in small type, thus assisting in the study and reference. The third part of the work will prove of great service to students who wish to acquire a practical knowledge of minerals in a short time, since they are apt to be confused by the mass of detail in the larger works.

Part IV. is entitled determinative mineralogy and contains tables for rapid determination of the common minerals. There are four of these tables, the first containing minerals of metallic or sub-metallic lustre, the second with blowpipe confirmations of the same; the third containing minerals without metallic lustre and their blowpipe tests, and the fourth with the physical characters as confirmation of the minerals of non-metallic lustre. G. PERRY GRIMSLEY.

Memoir of Sir Andrew Crombie Ramsay. By SIR ARCHIBALD GEIKIE Pp. 397. Macmillan & Co. Price, $4.00.

The biography of so distinguished a scientist as Sir Andrew Crombie Ramsay prepared by so appreciative a friend and so charming a writer as Sir Archibald Geikie could hardly fail to be of interest to geologists and geographers. The author has succeeded admirably in making the geniality and enthusiasm of Sir Andrew apparent, as well as in setting forth the distinguished service which he rendered to the science of geology. The memoir is much more than a mere biography. Sir Andrew was intimately connected with the geological survey of Great Britain for forty years, and an account of his work and of his influence, such as this memoir presents, involves a sketch of the history of the geological survey of the United Kingdom. Not only this, but Sir Andrew's connection with the survey brought him into such intimate relations with other geologists of his own and foreign lands, that his biographer has found it easy to weave into the memoir much general information concerning geologists and geological progress during the period of Sir Andrew's activity.

Portraits of a dozen of Sir Andrew's associates have been introduced into the memoir. These portraits are an attractive feature of the vol-

ume and enhance its interest for geologists. A list of the portraits, besides that of the subject of the memoir, is as follows: De La Beche, Logan, Aveline, Selwyn, Bristow, Gibbs, Oldham, Smyth, Jukes, Forbes, Murchison, and Salter. R. D. S.

Meteorology — Weather and Methods of Forecasting. Description of Meteorological Instruments and River Flood Predictions in the United States. By THOMAS RUSSELL, U. S. Assistant Engineer. Macmillan & Co., New York, 1895, pp. xxiii., 277. Illustrations and maps.

The scope of this new work on meteorology is indicated by the title page. As the author states in the preface, the main object of this book is to explain the use of the weather map, where it can be of use for the purpose of making predictions. The method is based mainly on statistics of the observed condition of the air as to pressure, temperature, and humidity of particular types, and the weather following twenty-four hours or more after the occurrence of the type. As a most important aid to this work the author gives a series of twenty-two type weather maps, each representative of about ten cases. Accompanying each of these are maps showing the rainfall (1) for the twenty-four hours preceding the date of the weather map (2) for the twenty-four hours succeeding, and (3) for the time from twenty-four to forty-eight hours after. By the aid of these maps the successful prediction of storms will be greatly aided.

The methods of predicting river heights for some important points along the lower Mississippi and its tributaries are given at some length. Rules and tables are given for computing the rise of floods when data from points higher up the stream are known. Another chapter is given to a brief description of various meteorological instruments, the list of which is quite complete. The principles involved in their construction are considered.

In addition to these topics, "almost everything that is considered to be of interest in relation to the weather is here given. The principal weather changes are described as they occur in various parts of the world in different seasons on land and sea, and their causes narrated so far as known. A collection of facts is given, useful in forming a conception of the phenomena of the atmosphere."

The chief criticism to be made of the book is lack of orderly

arrangement and scientific treatment. Long collections of facts are given, which not infrequently have no close logical or causal connection with each other. The book contains a vast amount of information, some of which is so incomplete as to be almost misinformation, arranged on the dictionary or encyclopædia style — interesting reading, but rather disconnected. It is to be feared that a beginner would form a very hazy notion of the science of meteorology, particularly of the broad principles underlying the details of the science from a perusal of it. As a reference book on some points and a storehouse of facts it is valuable to the student. The series of weather maps already alluded to cannot fail to be of great assistance. H. B. K.

Air-breathing Animals of the Palæozoic in Canada, up to 1894, by Sir Wm. Dawson, C.M.G., LL.D., F.R.S. Trans. Roy. Soc. Canada, Section IV., 1894, pp. 71–88.

"Our knowledge of the animal inhabitants of the land in Palæozoic time is very meager in comparison with what is known of marine creatures. There was probably less land in early Palæozoic ages than later. Atmospheric conditions may have been less favorable to breathers in air. Life on land requires a higher nervous and muscular system than those necessary in water, and different means of respiration." Animal life therefore probably originated in the waters. A long time may have been required to introduce the land life. The chances of preservation of aquatic organisms were much greater than were those of terrestrial species. The paucity of land fossils may be accounted for by these less favorable conditions.

The finding of Batrachian footprints by Logan in 1841 was the first indication of air-breathing vertebrates in the Carboniferous rocks. The first discovery of osseous remains of Palæozoic land vertebrates in America was that of *Baphetes planiceps* found by the author in the Pictou coal field in 1850. The first announcement of Devonian insects was from St. Johns, N. B., in 1862 by Hartt. Insects had previously been found in the Carboniferous of Europe, and have since been traced back to the Silurian. The earliest known Carboniferous millipede was *Xylobius sigillariæ*, discovered by the author in Nova Scotia in 1858. Many millipedes have since been found in the Carboniferous and Devonian on both sides of the Atlantic. The first known land snail was found by Lyell and the author at South Joggins in 1851.

This form of land life has since been found in other coal regions in America and in the Devonian plant beds of St. Johns, but not in Europe. Spiders and scorpions were found in the Palæozoic beds of Europe before they were recognized in America.

The known land animals of the Palæozoic of Canada embrace: *Vertebrata*, twenty-six species, all Amphibia; *Arthropoda*, thirty-three species, embracing insects, scorpions and myriapods, and *Mollusca*, five species of pulmonate snails. The author gives a classified list of these land fossils, with notes and brief descriptions of the new forms. Under the head of Vertebrata he observes that no land vertebrates have been recognized lower than the base of the Carboniferous system. Some Devonian fishes may have been endowed with a swimming-bladder capable of being used as an imperfect lung after the manner of the modern dipnoi. We may hope, however, yet to find land vertebrates in the Devonian.

The author adds a very interesting note on two erect stumps of trees recently found by Mr. P. N. McNaughton in the coal series at South Joggins. The hollow of one of these contained the fragmentary remains of nine species of vertebrates, including about thirty individuals. Besides this there were numerous fragments of millipedes, and rather rare remains of *Pupa vetusta*. The second stump contained remains of thirteen individuals, including four or five species. Both stumps occur at considerably lower horizons than the well-known stumps found many years ago by Lyell and the author.

The paper closes with helpful and stimulating suggestions to collectors. T. C. C.

Om klitternes vandring, by K. J. V. Steenstrup (Meddelelser fra Dansk Geologisk Forening, Bianco Lunos Kgl. Hof-bogtrykkeri, Kjöbenhavn, 1894).

Dr. Steenstrup calls attention to some characteristic features of the sand dunes on the west coast of Jutland. He has made out these features partly by observations in the field and partly by study of the topographical charts of the war department. These charts are constructed on a scale of 1 : 20,000 with contour-intervals of five feet, and exhibit well the topographic characters of the sand dunes. The author finds that the original shape of these wind-formed hills, seen in plan, is that of parabolic ridges, which have their concave and open side

toward the direction of the prevailing winds and away from the direction of their progression. The middle and most advanced part of the parabola tends to travel faster than the flanks, which are held back more effectively by the protecting growth of dune plants. In fact this center is often blown away entirely, and the flanks then remain as isolated nearly straight ridges which run approximately parallel with the direction of the prevailing winds. Such nearly straight and parallel ridges are therefore not to be regarded as independent formations, but rather as remnants of earlier loop-shaped ridges. The author also observes that the trend of the dune ridges changes in different localities with the changing proportions of the strongest prevailing winds. The direction inland, also, is a little different from the direction near the coast, but the cause for this difference is not yet very clear. It is shown that the dunes, in traveling over the land, do not always leave a deposit along their course. In several places it was noticed that the winds in the rear of the dunes have eroded the ground a few feet below the original level seen in front of the advancing sand. J. A. U.

A Great Pre-Glacial River in Northern Canada.

At the annual meeting of the Royal Society of Canada held in Ottawa on May 15, Professor Robert Bell of the Geological Survey read a paper on the above subject, illustrated by a map which he had prepared as the result of much study and extensive observation in the northern regions. We take the following report from the *Ottawa Journal*. It was, he said, generally conceded by geologists that just before the advent of the glacial epoch, the continent of North America stood at a considerably greater elevation than at present, the difference, according to some authorities, amounting to two or three thousand feet, if not more. The difference was greater towards the south, as compared with the present general altitudes. The inevitable result of this would be to greatly alter the river systems. We should find in northern Canada a wide central drainage area equal to about one-third of the present land surface of the continent, the center of which would be in the region now covered by Hudson Bay.

This great inland sea does not average 400 feet in depth, and it would be all dry land even with a very moderate elevation.

Hudson Strait is much deeper and it would either form a long bay or a river valley, according to the amount of the continental elevation.

Some geologists think that about this time the upper part of the St. Lawrence basin, including all the lakes, excepting Ontario, discharged its waters northward from Lake Superior. But even without this doubtful part the drainage area of this one great northern river would be seven times that of the present St. Lawrence. Judging from the ancient erosion of the valleys and from other considerations, the annual precipitation was at least as great then as now, so that this former river must have been of gigantic proportions compared with any river of the present world.

Its catch-basin would extend from the sources of the Saskatchewan and the Athabasca beyond the Rocky mountains to near the eastern coast of Labrador, and from the Minnesota river in the south to the northern part of Baffin Land and would also include the southern part of the great McKenzie basin. It would flow through the center of Hudson Bay and down Hudson Strait. The former existence of this great river was not a mere speculation as to what might have been, but a necessary consequence of the elevation and change in the slope of the land, and it was proved in detail by a multitude of concordant facts all over the territory involved.

Missouri Geological Survey. Vols. IV. and V., Palæontology of Missouri, by CHARLES ROLLIN KEYES, A.M., Ph.D., State Geologist, pp. 271 and 266. Vols. VI. and VII., Lead and Zinc Deposits, by ARTHUR WINSLOW, assisted by JAMES D. ROBERTSON, pp. xxi. + 763. Jefferson City, 1894.

The issuance in rapid succession of four volumes of the reports of the Missouri Survey indicates a laudable administrative activity. They bring us a grateful relief from the solicitude that was recently felt for the future of the survey. While much of the work of which these four volumes are an expression was done under the previous administration of Mr. Winslow and is to be credited to him and his colaborers, much credit is also due to the administration of Mr. Keyes for their present creditable issuance, as well as for his own large contribution to them.

Volumes IV. and V. relate to palæontology and were prepared by Director Keyes. Volume IV. opens with an introductory chapter on the nature and importance of palæontological data. This is followed by a synoptical description of the formations of Missouri, and a chapter on the biological relations of fossils, these three chapters being pre-

liminary to the descriptions of fossils which make up the remaining six chapters of the volume and the six chapters of the succeeding volume.

The grouping of the descriptions of fossils is biological, the chapters embracing Protozoans and Sponges (IV.), Hydrozoids and Corals (V.), Echinoids and Asterids (VI.), Cystids and Blastoids (VII.), Crinoids (VIII.), Worms and Crustaceans (IX.). These are in the main re-descriptions of species already known, the justification of this appearing in the author's introduction, in which the inaccessibility of the larger part of the original descriptions and the imperfection of some of them is urged. Twenty-one lithographic plates are given to illustrate the fossils described. An appendix containing a stratigraphic catalogue of Missouri fossils and a geological map of the state are added.

Volume V. is practically a continuation of Volume IV. and embraces six chapters relating to polyzoans, brachiopods, lamellibranchs, gasteropods, cephalopods and vertebrates. These are followed by an indexed list of the fossils of Missouri. Twenty-four illustrative plates accompany this volume.

Volumes VI. and VII. relate to the lead and zinc deposits, and are the work of ex-Director Winslow. As in the palæontological part, the separation into two volumes is merely a matter of mechanical convenience, the contents being closely consecutive. The subject is opened with a historical sketch of lead and zinc mining. The treatment is brief, but covers a wide range in time and geographic distribution. The nature of the metals is then discussed, followed by a chapter devoted to their distribution. Emphasis is laid upon the distinction between the diffused and the concentrated conditions, a distinction which is wholly determinative of their economic value, and scarcely less important in the study of their genesis. The ore deposits are classified successively on the basis of their composition, the mode of formation of the constituents, their sources, the forms of the ore body, the attitudes of the ore body, their structures, the natures of the associated substances, the natures of the calcareous rocks, and their geological position. A synoptical description of the lead and zinc deposits of foreign countries and of states other than Missouri occupies two chapters, and gives evidence of good judgment in the selection of the more important data. This is followed by a chapter prepared by James D. Robertson on the metallurgy of the metals, illustrated with cuts of

furnaces and other appliances, and accompanied by statistics of production.

The foregoing constitutes Part I. and is preliminary to the special discussion of the Missouri ores and the industry built upon them, which forms Part II. This embraces the history of mining in Missouri, discussions of the physiography of the mining districts and their general geology; a description of the ore deposits, under the heads of distribution, forms, composition, gangues, mineral types, structure and mode of formation, and further statistics regarding the lead and zinc industry.

Part III. is devoted to a detailed description of the mines in which the local occurrence of the ores is set forth with much fullness (200 pages of fine print, admirably illustrated by sections, sketches, maps and photographs).

To the geologist the chief interest of Mr. Winslow's important report doubtless centers in his discussion of the origin of the ores. He points out the grave objections to those hypotheses which postulate the derivation of the ores from solutions rising from great depths. His own opinion coincides in its main features with those of Whitney and Chamberlin respecting the analogous deposits of Wisconsin and adjacent states. He assigns the remote origin of the metalliferous material to the Archæan rocks, whence they were derived by surface decomposition. This material he believes was redeposited by the oceanic waters in the Palæozoic sediments whence it was rederived by surface decomposition and concentrated in the cavities where it is now found. He believes the diffusion of the metalliferous compounds in the Palæozoic sediments was general and rejects the view of Chamberlin that the localization of the deposits was partly due to local enrichment of the oceanic waters corresponding to local richness of the Archæan areas, partly to the courses the oceanic currents followed and partly to the topography of the sea bottom on which the metal-bearing sediments were laid down, aided by a differential distribution of the sea life which gave rise to the agencies of precipitation. He makes the concentration of the ores in the crevices purely secondary, the result of local conditions favorable to concentration. He appears in some slight degree to have misinterpreted Chamberlin's view in that he makes it inapplicable to rocks of different ages. To be sure the discussion of the Wisconsin deposits and the map of the currents were made specifically applicable to the Silurian deposits under immedi-

ate discussion, but the map recognizes that the ore deposits are of different ages and the context makes the hypothesis applicable to deposits of other ages. Of course changes in the courses of the currents, changes in the areas of derivation, and in those of deposition must be taken into consideration in explaining the later deposits. If the hypothesis urged by Chamberlin is good at all, it is applicable to all ages, because there must always have been different degrees of enrichment of the oceanic waters in different parts corresponding to the different amounts of metalliferous material brought in from the land and this must have been carried in the direction of prevailing currents. If the inequalities of the sea bottom tended to concentrate metalliferous deposits at one age they should do so at others under similar conditions. Mr. Winslow lays much emphasis upon the degradation of the formations whereby the disseminated metals were removed from their original matrix and brought together in the crevices or cavities in which the ores were accumulated. He justly points out the distinction between this and the narrow views of lateral secretion against which some authors have argued. Perhaps on his own part he is not wholly beyond criticism in the same direction in his interpretation of the views of Whitney and Chamberlin which are scarcely distinguishable from his own in this particular. The ideal diagram on page 548 of *The Ore Deposits of Southwestern Wisconsin*, Vol. IV., Geology of Wisconsin, very sharply emphasizes the function of surface decomposition, conjoined with concentration and segregation below. But this is rather a matter of nice toning and shading of opinion than of important distinctions. The report is much to be commended for its great array of facts which will form a memorable contribution to the science of ore deposits. Mr. Winslow has prepared a list of errata which he will gladly send to any desiring it. T. C. C.

Elementary Palæontology for Geological Students. By HENRY WOODS, B.A., F.G.S. [Cambridge University Press. Macmillan & Co., N. Y.]

This book will supply a want felt in all colleges where historical geology or palæontology is taught. It is something that has been lacking in the English literature on this subject. Though we have great palæontologists and have in our libraries numerous large and well written works on palæontology in various foreign languages and

some in our own, students wishing to get a clear idea of the foundation principles of the subject have been obliged either to wade through volumes of technical English works or to materially lessen their interest in the subject by struggling with the difficulties of a foreign language. The author presents in a condensed form the principal structural features of invertebrate fossils, and gives the generally accepted classification, with clear descriptions of the larger groups and principal genera. The book though perhaps too elementary for those taking up the study of palæontology with the intention of devoting considerable time to it, could still be used with profit for some time by such students. Its greatest usefulness will be, however, in aiding those who take up the natural sciences, for general culture only, to get a clear idea of the subject without becoming confused by a mass of details.

J. C. M.

Geological and Natural History Survey of Minnesota. N. H. WINCHELL, State Geologist, 1885–92. Geology of Minnesota, Vol. III., Part I., Final Report, Palæontology, by Leo Lesquereux, Anthony Woodward, Benjamin W. Thomas, Charles Schuchert, Edward O. Ulrich, Newton W. Winchell. 41 plates and 34 figures, pp. lxxv.+474. Published by the state. Minneapolis, Minn., 1895.

This important report opens with an excellent historical sketch of previous investigations of the Lower Silurian formations of the Upper Mississippi Valley by Professors Winchell and Ulrich. Students of the region will find this very convenient in directing them to the literature of the subject not only, but in giving them some indication of the conclusions reached in the works referred to. This is followed by a chapter on the Cretaceous fossil plants of Minnesota by the veteran palæobotanist, Leo Lesquereux. In the introduction to this, attention is called to the remarkably abrupt substitution of the Cenozoic flora for the Mesozoic flora in the midst of the Cretaceous period, and emphasis is laid upon the great diversity of the dicotyledonous forms upon their first appearance, and the lack of any satisfactory explanation of this phenomenon at present. Twenty-three species are described, of which seven are new. This is followed by a chapter on the microscopic fauna of the Cretaceous deposits in Minnesota, with additions from Nebraska and Illinois, by Anthony Woodward and Benjamin W.

Thomas. This is introduced by a description of methods in this relatively new field. Incidentally there is brought out the applicability of such microscopic studies to secondary deposits, such as the occurrence of the microscopic foraminifera in glacial clays. Twenty-nine species are described and fully illustrated. The chapter on sponges, graptolites and corals of the Lower Silurian formations is by N. H. Winchell and C. Schuchert and embraces descriptions and illustrations of nineteen species. This is followed by a chapter on the Lower Silurian bryzoa by E. O. Ulrich, which is introduced by a discussion of terminology, methods of study, classification and geologic distribution. It embraces descriptions of about 150 species, a large percentage of which are new. Twenty-eight lithographic plates, crowded with figures, are devoted to the illustration of this chapter. The final chapter is devoted to the Lower Silurian brachiopoda of Minnesota by N. H. Winchell and Chas. Schuchert. After a brief introduction upon preservation, distribution and terminology—the latter accompanied by very helpful diagrammatic illustrations—an excellent systematic description is given of the brachiopoda represented in Minnesota, exbracing eighty-four forms, amply illustrated. Altogether the volume is a very important addition to the palæontology of the interior. T. C. C.

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